Agenda

Smelting Symposium

Monday – 28.09.

18:00 – 22:00	*Welcome Reception*	

Tuesday – 29.09.

08:30 – 09:00	*Registration*	
09:00 – 09:15	*Welcome*	Moritz Eickhoff *RWTH Aachen University, Department of Industrial Furnaces and Heat Engineering*

DRI Smelting

09:15 – 10:05	"Electric smelting of DRI from Australian iron ore: process development from laboratory to intermediate scale"	Rolf Braun *University of Duisburg-Essen, Sustainable Metallurgy*
10:05 – 10:30	"Electric Smelting as a Key Enabler for Decarbonizing Integrated Steel Production"	Marcus Sommerfeld *ThyssenKrupp Steel Europe*
10:30 – 10:55	"Influence of Process Parameters on the Melting Behavior of DRI Pellets"	Stefan Andrä *TU Bergakademie Freiberg, The Institute of Iron and Steel Technology*

10:55 – 11:10	*Coffee Break*	

Modelling I

11:10 – 12:00	"Advanced CFD Modelling for Next-Generation Sustainable Metallurgy"	Mohamad Al Nasser *Technical University of Leoben, Chair of Simulation and Modelling of Metallurgical Processes*
12:00 – 12:25	"Numerical investigation of heat transfer and fluid flow in a pilot scale Electric Smelting Furnace"	Umair Jamil Ur Rahman *Tata Steel, R&D Green Iron & Steelmaking*
12:25 – 12:50	"Advances in Plasma and Arc Modelling within the PlasmArc4Green Initiative"	Hamideh Hassanpour *K1-MET, Area 3 Simulation and Data Analyses*

12:50 – 14:20	*Lunch*	

Smelting Symposium

Tuesday - 29.09.

By-Products

14:20 - 14:45	"Integration of Complex Metallurgical By-Products in Electric Smelting Furnace Operation: Process Strategy and Target Outcomes within CircSmeltSteel"	Alexander Halwax *K1-MET, Area 1 Metallurgical Process Efficiency & Circularity*
14:45 - 15:10	"Metallothermic Treatment of EAF smelting slag for cementitious slag application and circulation of metals"	Fiona Pickart *RWTH Aachen University, Institute IME Process Metallurgy and Metal Recycling*
15:10 - 15:35	"Milliseconds in the model, 40 minutes in the lab: Laser OES slag analysis at the furnace"	Alexander Schlemminger *QuantoLux, Innovation*

15:35 - 15:50	*Coffee Break*	

Modelling II

15:50 - 16:15	"A Time-Dependent Pellet Melting Approach for Modeling Feed Pile Formation in an Electric Smelting Furnace"	Saeed Tavakoli *Delft University of Technology, Mechanical Engineering, Transport Engineering and Logistics*
16:15 - 16:40	"Computational Thermochemistry Tools for Modelling Smelting Processes"	Joao Rezende *GTT-Technologies*

16:40 - 16:45	*Summary*	Moritz Eickhoff
16:45 - 18:30	*Pause*	
18:30 - 23:00	*Social Event*	

Smelting Symposium

Wednesday - 30.09.

08:30 - 09:00	*Arrival*	
09:00 - 09:05	*Welcome*	Ville-Valtteri Visuri *University of Oulu, Process Metallurgy Research Unit*

Process Technology I

09:05 - 09:55	"Contribution of Institute of Iron and Steel Techology to transformation of German Steel Industry"	Olena Volkova *TU Bergakademie Freiberg, The Institute of Iron and Steel Technology*
09:55 - 10:20	"Small and large Submerged Arc Furnaces for Mineral Wool Production"	Thorge Künkel *RWTH Aachen University, Institute of Mineral Engineering*
10:20 - 10:45	"Capabilities and Operational Experience of Pilot-Scale SAF and EAF Facilities"	Frida Vollan *SINTEF*

10:45 - 11:00	*Coffee Break*	

Process Technology II

11:00 - 11:25	"Supplying power to submerged-arc furnaces: System design and operation"	Vetle Kjær Risinggård *NORCE Norwegian Research Centre, AS*
11:25 - 11:50	"An overview of electrode systems applied in different smelting technologies"	Yuriy Lytvynyuk *Elkem, Carbon AS*
11:50 - 12:15	"Performance of Selected Refractory Materials for Hot Metal Production under Laboratory-Scale ESF Conditions"	Lukas Höcher *Technical University of Leoben, Chair of Ferrous Metallurgy*

12:15 - 12:25	*Summary*	Moritz Eickhoff
12:25 - 13:55	*Lunch*	

Electric smelting of DRI from Australian iron ore: process development from laboratory to intermediate scale

Rolf Braun[1], Craig Garlick[2], Tejbir Singh[2], Abrar Taimullah[2], Lucas Horn[1], Hauke Springer[1], Anthony Rich[3], Tom Honeyands[2]

[1]Chair of Sustainable Metallurgy, University of Duisburg-Essen, [2]BHP Centre for Sustainable Steelmaking Research, University of Newcastle, [3]BHP Marketing Sustainability

While the Electric Smelting Furnaces (ESF) process is well established for the production of ferroalloys, it only recently has begun to receive attention in the context of lowering the CO2 emissions of steel production. The inherent reduction capabilities result in increased flexibility for the upstream direct reduction process of iron ores. Furthermore, with property profiles of both slag and hot metal being potentially similar to the output of blast furnaces, the downstream processing of both cement and steel, respectively, is greatly facilitated. These characteristics make the ESF process attractive for processing DRI from sources such as medium grade Australian iron ores to make hot metal suitable for steelmaking, however the metallurgy and process engineering aspect require further development for specific material combinations. In particular, the immersed electrode smelting in partial open bath presents challenges for the experimental investigation of metal/slag reactions in non-isothermal and non-equilibrium conditions. Here we present insights into the collaborative work at the University of Newcastle laboratory scale (<10kg) and the University of Duisburg-Essen intermediate scale (up to 150kg charge) to investigate ESF process metallurgy. Following an overview of the general capabilities of the facilities, the successful development is demonstrated on results from ESF experimentation using a DC power supply for two immersed electrodes providing resistance heating in the slag. The unique features of smelting in quasi steady-state conditions are demonstrated in the processing of DRI resulting in a hot metal carbon at greater than 3.5% and a slag containing less than 1% Fe.

29.09. – 10:05 to 10:30

Electric Smelting as a Key Enabler for Decarbonizing Integrated Steel Production

Marcus Sommerfeld, Matthias Fabry

thyssenkrupp Steel Europe AG

To address one of the biggest challenges of our generation, anthropogenic climate change, the iron and steel industry has major technological levers at its disposal to reduce the annual greenhouse gas emissions. thyssenkrupp Steel Europe follows a unique decarbonization pathway, which includes the replacement of a blast furnace with a direct reduction plant and two electric smelting furnaces as a major contribution to reduce specific carbon dioxide emissions. This brownfield project, with an annual capacity of 2.5 million tons of direct reduced iron followed by electric smelting for hot metal production, is unprecedented at this scale and for this combination of raw materials and products.

The presentation will introduce the boundary conditions and rationale for the implementation of the direct reduction – electric smelting – basic oxygen furnace route at thyssenkrupp Steel Europe in Duisburg, Germany. In addition to the industrial plant, a pilot-scale facility is currently under construction to support future operations, especially in terms of raw material selection and innovative operating concepts. A brief overview will be provided of the current status of the pilot facilities.

29.09. – 10:30 to 10:55

Influence of Process Parameters on the Melting Behavior of DRI Pellets

Stefan Andrä, Olena Volkova

Institute of Iron and Steel Technology of TU Bergakademie Freiberg

The direct reduction process is proposed to supersede the conventional blast furnace ironmaking process in Germany and Europe in the coming decades, in order to reduce carbon dioxide emissions in steelmaking. However, a fundamental difference between direct reduction technologies and blast furnace ironmaking is that the product consists of solid direct reduced iron (DRI). In order to allow further processing into finished steel, it needs to be melted. Several different technologies have been proposed to melt DRI pellets, including conventional EAF processes and Submerged Arc Furnaces (SAF).

In the present work, the influence of both direct reduction parameter, such as direct reduction temperature and gas composition, as well as melting parameters, including melt temperature and composition, have been investigated. To this end, an experimental procedure has been proposed where DRI reduced under different parameters have been added to a melt, and melting behavior observed via diameter reduction as a function of time. Experiments have been conducted in pig iron at 1400 °C and 1500 °C as well as crude steel at 1550 °C.

It has been found that the fastest average melting rate occurs in pig iron at 1500 °C, followed by crude steel at 1550 °C, indicating a significant influence of chemical composition on the melting rate. The resulting slags have also been analyzed, showing that they consist mostly of iron oxides and silicon oxides, congruent with current conventional EAF slags.

29.09. – 11:10 to 12:00

Advanced CFD Modelling for Next-Generation Sustainable Metallurgy

Mohamad Al Nasser, Christian Gomes Rodrigues, Ebrahim Karimi-Sibaki, Menghuai Wu, Abdellah Kharicha

Christian Doppler Laboratory for Reactive Flows in Green Steel Production and Refinement, SMMP, Technical University of Leoben

Steelmaking produces roughly 7–9% of global CO_2 emissions, mostly from the coal- and gas-based blast furnace (BF) route. Electric smelting furnaces (ESFs) and electric arc furnaces (EAFs) are central to decarbonizing primary iron production: ESFs can replace the BF as the source of liquid hot metal, melting direct-reduced iron (DRI) with greater tolerance to low-metallization feed than an EAF. Our group has developed physics-based CFD models for metallurgical processes covering electromagnetic, fluid-flow, thermal, and solidification phenomena; this work highlights key applications.

At the furnace scale, a magnetohydrodynamic (MHD) model of an industrial smelter couples arc plasma with molten slag and metal dynamics, resolving current distribution, arc–bath interaction, arc radiation, and arc-shear loading of the refractory walls; predicted flow patterns and thermal fields agree closely with industrial data. A complementary EAF model treats DRI and scrap melting alongside slag foaming in a simplified Eulerian two-phase framework. A transient 3D model of an atmospheric-pressure DC arc resolves highly dynamic MHD flows, benchmarked against air arcs to guide hydrogen integration into greener steel routes.

A solidification framework coupling heat transfer, fluid flow, and phase change captures freeze-lining growth in slag-containing furnaces. It has been validated against laboratory-scale experiments and an industrial slag fuming furnace, then applied to an ESF using literature data. These capabilities support the design and optimization of ESFs, EAFs, and other slag-containing furnaces, where controlled freeze-lining formation is critical for energy efficiency. Ongoing work extends the approach to hydrogen-based electric smelting, with experimental validation planned, supporting low-carbon metallurgy.

29.09. – 12:00 to 12:25

Numerical investigation of heat transfer and fluid flow in a pilot scale Electric Smelting Furnace

Umair Jamil Ur Rahman

Tata Steel Nederland

Tata Steel Nederland is exploring low-carbon steelmaking routes, including the potential implementation of an Electric Smelting Furnace (ESF). Compared with conventional EAF technology, the ESF can process lower-grade iron ores while retaining the existing BF-BOF route. However, the technology remains at a relatively low Technology Readiness Level (TRL) for hot metal production, creating significant technical risks. CFD provides a valuable tool for investigating the complex heat transfer mechanisms governing ESF operation.

In this study, a two-dimensional multiphase CFD model of a pilot-scale ESF was developed to investigate thermal interactions between the slag, hot metal, and feed pile. The slag-hot metal interface was captured using a Volume of Fluid approach, while Joule heating was represented as a volumetric heat source under the electrode. Feed pile melting was modeled through temperature boundary condition corresponding to the liquidus temperatures of slag and hot metal. Due to limited experimental data, assumptions were made regarding the feed pile geometry.

The simulations revealed temperature gradients of up to 1000 °C within the slag, primarily attributable to its low thermal conductivity. Furthermore, approximately 80% of the melting heat to the feed pile was transferred through the slag-pile interface. Parametric analysis further showed that increasing the distance between the feed pile and the electrode enhanced heat transfer to the hot metal due to increase of interfacial area between the slag and hot metal. In addition, deeper electrode immersion improved heat transfer by promoting stronger convective mixing and closer proximity of the heat source to the slag-hot metal interface.

29.09. – 12:25 to 12:50

Advances in Plasma and Arc Modelling within the PlasmArc4Green Initiative

Hamideh Hassanpour, Damir Kahrimanovic, Magdalena Schatzl, Christine Gruber

Area 3 – Simulation & Data Analyses, K1-MET

Plasma and electric-arc technologies are increasingly recognized as key enablers for the decarbonization of metallurgical processes. Within the COMET Module PlasmArc4Green (PA4G), extensive simulation activities have been carried out to establish a deeper understanding of plasma-driven processes and to create predictive tools for the design and optimization of future green-metallurgy technologies.

The project has brought together expertise in plasma physics, plasma-material interactions, advanced characterization, and process modelling to develop simulation frameworks spanning multiple scales. The resulting capabilities enable the investigation of plasma generation and transport processes, arc stability, energy and momentum transfer, plasma–electrode interactions, and the coupling between plasma arcs and metallurgical reactors.

Building on these developments, the simulation tools have been applied to Hydrogen Plasma Smelting Reduction (HPSR), allowing the analysis of plasma behaviour, heat transfer, electromagnetic forcing, and bath mixing under industrially relevant conditions. Recent studies have demonstrated how plasma composition influences arc characteristics, melt heating efficiency, and liquid-metal circulation, providing valuable guidance for process optimization.

The presentation will provide an overview of the modelling achievements within PA4G and discuss ongoing efforts to extend these capabilities towards industrial smelting furnaces, including submerged-electrode and AC furnace operation, as part of the roadmap towards simulation-driven development of sustainable plasma-based metallurgical processes.

29.09. – 14:20 to 14:45

Integration of Complex Metallurgical By-Products in Electric Smelting Furnace Operation: Process Strategy and Target Outcomes within CircSmeltSteel

Alexander Halwax

K1-MET GmbH

The Electric Smelting Furnace (ESF) is increasingly recognised as a viable low-CO2 ironmaking technology. However, systematic process data for ESF operation with high shares of metallurgical by-products, including slag electrical conductivity, slag-metal equilibria, and stable operating windows, remain scarce. Existing research on residue valorisation has primarily focused on EAF-based routes, leaving agglomerate behaviour under ESF-specific reducing atmospheres insufficiently characterised.

Within the Horizon Europe project CircSmeltSteel (GA No. 101294187), complex by-products with mean Fe contents of ~40 wt.-% (e.g., BOF slag, EAF dust; feed shares up to 50%) will be combined with reductants and binders to produce cold-bonded briquettes or micro-granules. Recipe formulation and agglomeration parameters will be systematically optimised and evaluated using induction melting, TGA, and DSC.

Subsequent ESF trials, at pilot batch scale (1 t) and at semi-industrial continuous scale (2–3 t/h), will examine brush-arc and immersed-electrode operation to determine their specific effects on Fe yield and slag chemistry. Furthermore, thermodynamic calculations via FactSage® and Thermo-Calc® form the basis for optimal slag former addition. Key physical properties, including slag viscosity, electrical conductivity, and cementitious utilisation potential, will be evaluated as a function of feed composition and temperature. A dynamic process model will consolidate these findings to enable extrapolation toward industrial-scale operation.

The aim of CircSmeltSteel is to close knowledge gaps in ESF process control with complex secondary feeds - targeting, 85% glass content in the slag - and to establish a validated basis for industrial scale-up of this route in circular steelmaking.

29.09. – 14:45 to 15:10

Metallothermic Treatment of EAF smelting slag for cementitious slag application and circulation of metals

Fiona Pickart

IME Process Metallurgy and Metal Recycling at RWTH Aachen University

Electric arc furnace (EAF) steelmaking, the dominant secondary steel production route, generates significant amounts of slag as a by-product. While EAF slag has long been considered for cementitious applications, its recycling potential remains limited by two major issues:
Their high iron oxide content lowers the phase fraction of CaO, Al_2O_3, and SiO_2 which are needed for the formation of calcium aluminates (CA) and calcium aluminium silicates (CAS), the main contributors to the hardening mechanisms in cement. Secondly, the contents of heavy metals are strictly regulated due to the health risks they pose. The limits, imposed for example by the German Substitute Building Materials Ordinance (ErsatzbaustoffV), are often significantly below those reached in metallurgical processes.

A possible solution is suggested by metallothermic reduction of EAF slag with Si and/or Al metal. This will simultaneously lower the heavy metal contents while increasing the required Al_2O_3 and SiO_2 contents. A suitable laboratory setup was developed to treat artificial EAF slag with metallic Si. In these trials the reduction of Fe, Cr and Mn could be proven. Further, the elution behavior of Cr from the slag was tested, all values stayed under the legal limits.

Improvements to the setup like a granulation procedure need to be implemented to reliably rate the slag’s suitability as a secondary cementitious material.

29.09. – 15:10 to 15:35

Milliseconds in the model, 40 minutes in the lab: Laser OES slag analysis at the furnace

Alexander Schlemminger

QuantoLux Innovation GmbH

A CFD model of an electric smelting furnace resolves the arc in milliseconds. The slag composition that model runs on comes from one laboratory sample per tap and reaches the operator 30 to 40 minutes later. Everything in between is interpolation.

For some years now slag can be measured at the furnace instead. Laser Optical Emission Spectrometry, Laser OES or LIBS, fires a pulsed laser on the crushed sample and evaluates roughly 10,000 single spectra per result, so the data are homogenised and not the sample. No grinding, no pressing, no fusion. Ca, Si, Fe, Mg, Al, Mn, Cr, P, Ti and S, reported as oxides and as basicity, in one minute.

Several samples per heat give a composition curve instead of a single value at the end. The FeO trend can be followed while it is still moving, and viscosity or liquidus calculations run on compositions somebody actually measured.

Now the part that matters for this audience. The method only knows what it has been calibrated on. Our calibrations cover EAF and ladle slag, and the same approach has meanwhile been carried over to applications outside steel. Smelter slag from low grade DRI sits partly outside them, higher Al_2O_3, TiO_2 depending on the ore. There we have no number yet. So, we are looking for samples with reference analyses from smelter pilots and plants.

29.09. – 15:50 to 16:15

A Time-Dependent Pellet Melting Approach for Modeling Feed Pile Formation in an Electric Smelting Furnace

Saeed Tavakoli[1], Jan-Thijn Wijnker[1], Ali Emami[2], Geert Keetels[1], Dingena Schott[1]

[1]Delft University of Technology, [2]Tata Steel Nederlands

To achieve its target of reducing CO_2 emissions by 70%, Tata Steel Nederland (TSN), through the Dutch National Growth Fund program Groeien met Groen Staal (GGS), is investigating the Electric Smelting Furnace (ESF) as a potential future ironmaking technology. In the ESF, top-charged Direct Reduced Iron (DRI) pellets and additives form a feed pile that gradually melts through interaction with the underlying slag and hot metal layers. The behaviour of this feed pile remains a key uncertainty, as it directly influences heat transfer and overall furnace performance. This study presents a time-dependent numerical framework, supported by experimental observations, to investigate feed pile formation and evolution under ESF operating conditions.

A coupled Discrete Element Method (DEM) and Computational Fluid Dynamics (CFD) model is developed to investigate interactions between DRI pellets and the surrounding molten phases. Two extreme interface scenarios are considered: complete slag penetration and a dry pile with limited slag penetration. Experimental trials involving pellet charging onto molten metal show penetration only a few pellet layers deep, indicating that practical ESF operation is likely closer to the dry pile scenario.

Based on these findings, a pellet-scale melting model is integrated into the DEM framework. The model describes shell formation, shell remelting, and core melting, while a Johnson–Kendall–Roberts (JKR) cohesion model accounts for inter-pellet bonding during melting. The framework is applied to assess the influence of key process variables and material properties on feed pile growth and melting behaviour, providing insights to support future ESF design and operation.

29.09. – 16:15 to 16:40

Computational Thermochemistry Tools for Modelling Smelting Processes

Joao Rezende, Shivani Gonde, Philipp Keuter, Moritz to Baben

GTT-Technologies

Increasingly complex feed materials, fluctuating raw material quality, and growing demands for energy efficiency are driving the need for advanced process models in modern pyrometallurgy. Computational thermodynamics provides a rigorous framework for analysing and optimizing industrial smelting processes.

This contribution presents thermodynamic process modelling approaches using FactFlow, as implemented in FactSage 8.4, and ChemApp for Python. These complementary tools combine equilibrium thermodynamics with mass and energy balances and process flowsheet simulation to investigate the influence of operating conditions, feed composition, flux additions, and process configurations while maintaining thermodynamic consistency.

Two application examples are presented. As a first example, a simplified FactFlow model for the production of Ferromanganese (FeMn) by the carbothermic reduction of manganese oxides in an electric submerged arc furnace (SAF) is presented. As a second example, an integrated copper smelting flowsheet is presented, demonstrating how interconnected unit operations can be represented within a thermodynamically consistent process model to evaluate the influence of ore quality and operating parameters on process performance. The same modelling approaches are readily transferable to other electric smelting and recycling processes.

Contribution of Institute of Iron and Steel Techology to transformation of German Steel Industry

Olena Volkova

Institute of Iron and Steel Technology of TU Bergakademie Freiberg

This presentation will cover current research activities of Institute of Iron and Steel Technology TU Bergakademie Freiberg in the field of hydrogen metallurgy. Examples include (i) direct reduction of BF and DRI-pellets as function of temperature, gangue, flow rate and gas mixture; (ii) effect of electromagnetic fields (EMF) of varying frequencies on the reduction process of iron oxides; (iii) isothermal and dynamic swelling index of BF and DRI-pellets during hydrogen reduction; (iv) the recycling of BOF dusts using hydrogen; (v) hydrogen reduction of liquid EAF slag; (vi) desulphurisation of liquid crude steel with hydrogen; (vii) hydrogen solubility in crude steel.

Smelting Symposium

30.09. – 09:55 to 10:20

Small and large Submerged Arc Furnaces for Mineral Wool Production

Thorge Künkel

Institute of Mineral Engineering, RWTH Aachen University

Unlike other processes in the fibre and glass industry, in the production of rock mineral wool the melting is affiliated with a second process of almost equal importance: The controlled reduction of the raw materials' polyvalent constituents. The right redox state of the polyvalent ions is essential in reaching the key properties of rock mineral wool, most importantly the prolonged fire resistance. The conventional production therefore bears similarities to a blast furnace – using coal coke and air to provide a low-pO_2 atmosphere for both heating and reduction. Still, steps towards higher sustainability are undertaken. For example, the use of natural gas instead of coke significantly lowers CO_2 emissions, but it solves neither the dependency on fossil fuel based energy, nor significant problems like the by-production of unusable pig iron.

Electric melting is another route, achieving multiple advantages at once. Not only does electric melting reduce the carbon footprint of the melting process to almost zero when using green electricity, it also decouples the heat input from the reduction of polyvalent constituents, which then can be achieved by using secondary material and regenerative carbon, boosting sustainability further. This allows for a better control and decreased pig iron production.

In this talk, I present my work on the use of Submerged Arc Furnaces towards melting of rock mineral wool batches, the challenges and advantages of the process, and the design, construction and operation of our own Submerged Arc Melter in small (SAMs) at the Institute of Mineral Engineering, here at RWTH.

Smelting Symposium

30.09. – 10:20 to 10:45

Capabilities and Operational Experience of Pilot-Scale SAF and EAF Facilities

Frida Vollan, Ingeborg Solheim, Trygve Lindahl Schanche, Halvor Dalaker, Rannveig Kvande

SINTEF AS

The development of metallurgical processes requires access to flexible pilot-scale infrastructure capable of bridging the gap between laboratory studies and industrial implementation. This presentation provides an overview of SINTEF's Submerged Arc Furnace (SAF) and Electric Arc Furnace (EAF) facilities, together with the associated equipment and experimental capabilities that support the full process development chain.

The facilities offer comprehensive support from material characterization and pre-qualification, through feed preparation and thermal treatment, to pilot-scale smelting, process monitoring, and product characterization.

With the power supply forming the heart of the installation, the SAF facility is designed around interchangeable reactor configurations that can be adapted to the specific process under investigation. While recent activities have primarily focused on manganese and silicon alloy production in submerged arc furnace mode, the facility has also been utilized for a range of alternative pyrometallurgical applications. These include open-bath melting and smelting campaigns, as well as studies aimed at valorisation of industrial side streams and secondary resources. This flexibility enables the facility to support both established industrial processes and the development of emerging technologies.

Selected results from previous research and industrial projects will be presented to demonstrate the breadth of applications, operational experience, and insights gained through pilot-scale experimentation. Finally, the presentation will discuss future opportunities for collaborative projects and emerging process concepts, illustrating how the facilities can contribute to the development of more resource-efficient and sustainable metallurgical technologies.

30.09. – 11:00 to 11:25

Supplying power to submerged-arc furnaces: System design and operation

Vetle Kjær Risinggård, Ida Monsen

NORCE Research AS

The electrical power supply and control systems are essential and understudied parts of submerged-arc-furnace design and operation. Design and operating decisions strongly affect capital expenditure, energy efficiency, and operational stability.

Beginning upstream of the furnace, furnace transformers and capacitors used for reactive power compensation represent a substantial share of power-supply capital expenditure and electrical energy losses. Traditionally, reactive power compensation is installed on the transformers' high-voltage side. Circuit modeling demonstrates that low-voltage-side capacitor connections can substantially reduce transformer size, but require larger capacitors in a more critical location.

Downstream of the transformers, busbars and flexibles are the second largest source of the total electrical energy losses. In high-voltage-compensated systems, circulating currents may develop on the transformers' low-voltage side and increase these losses. Circuit modeling, compared with high-frequency electrical measurements, indicates that current paths through the furnace burden likely produce the asymmetry responsible for these circulating currents.

Electrode actuation determines the power distribution within the furnace. Current control systems often experience interaction effects, especially in current control, due to the use of three parallel single-electrode control loops. Additionally, resistance control relies on complex electrode-voltage measurements. Simultaneously actuating all three electrodes, using only electrode-current measurements, addresses these issues and may promote more stable operation. We present a new decomposition of electrode currents that provides a foundation for such a system. The electrical power supply and control systems are essential and understudied parts of submerged-arc-furnace design and operation. In particular, design and operational decisions strongly affect the capital expenditure, energy efficiency, and operational stability.

30.09. – 11:25 to 11:50

An overview of electrode systems applied in different smelting technologies

Yuriy Lytvynyuk, Heidi Feldborg

Elkem Carbon AS

The most commonly used electrode technology for ferroalloy production worldwide is the self-baking Søderberg electrode system. An overview of electrode systems applied in different smelting technologies is described. The challenge is to select the most suitable system having the lowest operational cost and also having the lowest CAPEX. The equipment of the cylindrical and the modular holder designs used in AC smelters are compared in this study. For technologies operating with low and intermediate current load electrodes the modular holder can be beneficial as it has simplified design and requires lightweight equipment and less spare parts. A recent trend, especially in China, is a transition from AC technology to DC technology also for submerged arc furnaces, while still using Søderberg electrodes. The target of that transition is the improvement of the power consumption in technologies operating with relatively low power factors. The pros and cons for the different electrode systems will be discussed.

30.09. – 11:50 to 12:15

Performance of Selected Refractory Materials for Hot Metal Production under Laboratory-Scale ESF Conditions

Lukas Höcher[1], Matheo Rossegger[1], Christoph Thaler[2], Daniel Ernst[1]

[1]Technical University of Leoben, [2]voestalpine steel GmbH

Direct reduction is a key technology for reducing greenhouse gas emissions in the steel industry. While current processes mainly rely on high-grade iron ores, the increasing use of medium- and low-grade ores will require alternative melting technologies due to the higher slag volumes associated with the resulting direct reduced iron (DRI). The electric smelting furnace (ESF) has emerged as a promising option for processing such DRI into hot metal and slag. However, as this technology is still under development, the suitability of refractory lining materials must be assessed.

The aim is to investigate the wear behavior of magnesia and carbon bonded magnesia crucibles under laboratory-scale ESF conditions. Inert melting experiments are performed using a transferred arc laboratory reactor at the Chair of Ferrous Metallurgy at Montanuniversitaet Leoben. Various synthetic FeO-containing slags with FeO contents of approximately 40–60 wt.% are melted together with hot briquetted iron (HBI) in refractory crucibles and held in the liquid state for a defined period. No carbonaceous reductants are added to keep the focus solely on the interaction between these slags and refractories under arc operation. During the experiments, sample collection in predetermined intervals monitor changes in the slag composition. Samples are analyzed using SEM/EDX. As a result, any interactions between slag and refractory material are identified. After the tests, the crucible cross-sections are examined using a digital microscope and SEM to qualitatively evaluate refractory wear. The findings will contribute to the selection of suitable refractory materials for future ESF applications.