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Dynamic Modeling and Optimization of Electric Arc Furnace Operation: Coupling Energy, Oxygen, and Slag Chemistry

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Electric Arc Furnace (EAF) steelmaking is increasingly central to modern steel production due to its ability to operate with low-carbon feedstocks and flexible charging strategies, yet its behaviour is far from steady-state. Energy input, oxygen lancing, carbon for slag foaming, flux additions, continuous slag removal and semi-continuous charging interact throughout the heat, making the process highly dynamic. Conventional KPIs capture these variables individually, but they do not explain how changes in one input propagate through temperature, FeO formation, basicity development or tap-to-tap performance. This work focuses on bridging that gap through the development of a dynamic, data-supported model that links furnace inputs to thermal and slag-phase outcomes using real industrial evidence.
The objective of this work is to understand how oxygen and carbon injection, flux additions, and energy input from electrical arcs and chemical reactions influence temperature development and slag behaviour during the heat. To achieve this, 100 consecutive heats from a semi-continuous EAF were analysed. The dataset includes electrical and chemical energy input, carbon and oxygen injection rates, charge and flux additions, as well as measured temperature readings through the heat. Slag samples provide FeO, P2O5 and CaO-SiO2 data for benchmarking the model against industrial behaviour. Temperature evolution is modelled using mass and energy balance principles, accounting for electrical heat input, chemical reactions and heat losses. A parallel slag-reaction module tracks FeO formation and basicity change as a function of time-varying oxygen and flux practice.
Preliminary results show that the model captures overall temperature progression with reasonable agreement to plant measurements, and input-output correlations indicate that oxygen and carbon practice influence slag chemistry and thermal rise. CaO and FeO trends follow expected dephosphorisation behaviour, and variations in slag removal during the heat are reflected more accurately when linked to CO generation signals rather than assumed to be constant. These relationships form the basis for identifying where operational decisions have the strongest downstream impact, without yet claiming full predictive optimisation.
This work contributes a physically grounded modelling approach that clarifies how furnace practice drives slag evolution and temperature response in semi-continuous EAF operation. The results establish the modelling foundation upon which future optimisation, control logic and simulation studies can be developed as more heats and slag data become available.
Keywords: Electric Arc Furnace, dynamic modelling, oxygen efficiency, slag chemistry, energy optimization, semi-continuous operation, industrial validation.

Speaker Country

Finland

Speaker Company/University

University of Oulu

Primary author: Mr AGNIHOTRI, Ankur (University of Oulu)

Co-authors: Mr KENDALL, Martin (Heraeus Electro-nite); Dr SULASALMI, Petri (University of Oulu); Prof. VISURI, Ville-Valtteri (University of Oulu)

Presenter: Mr AGNIHOTRI, Ankur (University of Oulu)

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