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Hybrid Metallurgical and Machine Learning Model for Temperature Prediction in DRI-Based EAF

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Electric Arc Furnace (EAF) steelmaking is an energy-intensive and highly dynamic process in which accurate bath temperature prediction is essential for stable refining, energy optimization, and minimizing tap-to-tap variability. This study develops a hybrid temperature prediction framework by integrating first-principles metallurgical modeling with machine-learning validation using historical operational data from a DRI-based EAF. A detailed heat-balance model was constructed to capture the major thermochemical interactions governing temperature evolution, incorporating FeO reduction kinetics, carbon dissolution from DRI, slag formation thermodynamics, electrical energy input behavior, oxygen injection effects, and heat losses through off-gas and water-cooled panels. These physics-based calculations provide a mechanistic foundation that reflects the true metallurgical pathways of a DRI-intensive furnace. To enhance predictive accuracy, the physical model was fine-tuned through machine-learning correction using industrial heat datasets. The hybrid model demonstrated strong agreement with measured temperatures, achieving high R^2(0.9) values and low RMSE(12) across validation heats, thereby confirming its reliability under varying operating conditions. The results show that implementing this hybrid framework can reduce temperature deviations, improve energy utilization, and minimize operator-driven corrective actions. Overall, this work demonstrates that combining first-principles metallurgical knowledge with data-driven machine learning provides a practical, scalable approach for real-time temperature prediction and supports digitalized, energy-efficient, and sustainable EAF steelmaking.

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