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Data-driven predictions of castability in low-alloyed steels with the aid of ab-initio datasets

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Continuous casting is often hindered by the clogging of submerged entry nozzles (SEN), caused due to the agglomeration of non-metallic inclusions (NMIs). SEN clogging is challenging to monitor and requires probabilistic models for online predictions of 'castability'. In this context, data-driven models emerged as a promising tool to be used in the existing industrial settings. Despite the occurrence of SEN clogging, collecting large datasets under both 'good' and 'bad' SEN conditions remains challenging due to the stochastic nature of clogging. This results in a natural imbalance in the input data, where instances of 'good' castability vastly outnumber those of 'bad' castability. The scarcity and imbalance in this data hampers the ability to develop and train traditional data-driven models effectively. To overcome these challenges, a physics-informed data-driven model was proposed in this work. A physics-informed approach integrates explicit physical principles into data-driven frameworks, increasing model's capability to utilize limited data while adhering to known physical laws. The steel chemistry from low alloyed aluminum killed steel grade was considered for the formulation of data-driven model, employed with a hybrid approach of Adaptive Neuro Fuzzy Inference System (ANFIS) and Long-Short Term Memory (LSTM) networks. The actual ground truth of 'castability' was approximated by a 'Castability Index' parameter. The integration of outputs generated from physics-informed calculations provided sufficient to compensate for the lack of process data. To further enhance accuracy, an advanced methodology involving use of ab-initio data repository was developed. This repository contained material-specific data including high-temperature non-retarded Hamaker constants of NMIs comprising Al_2O_3, CaO, MgO, and CaS in specific particle size range of 1-10 µm. A novel parameter 'Clogging Factor' was proposed to monitor the output generated from physics-informed models. This offered significant advantages for steelmaking process control for more realistic and reliable predictions than traditional data-only approaches. While the model's effectiveness in reducing SEN clogging demonstrated its practical value, the proposed physics-informed data-driven strategy still awaits validation in online industrial settings.

Keywords: Ab-initio, Castability, Clogging, Data-driven, Online, Steelmaking

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