Vortexing at the Meniscus of Continuous Casting Mould: Experiment, Simulation and Plant Data Analysis

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Abstract

Continuous casting process is widely employed to solidify over 95% of steel in the world. Multiphase fluid flow in mould region is of great interest and particularly the complex flow structures at the top surface as they regulate the mould powder entrainment, a prime cause for both surface and internal defects in the final product. Analysis of the plant data revealed that 42% of the slivers, line defects, generated at Tata Steel, Jamshedpur are due to mould powder entrainment. Among the multiple mechanisms that can cause entrainment, vortexing at mould meniscus is of prime importance. Hence, a deeper knowledge of vortexing at the meniscus is inevitable. It is with this intention that the present work has been undertaken.

Application of data science techniques on process data yields profound insights. In this contribution, at first, we aim to classify the detrimental operating conditions leading to mould powder entrainment using clustering approach. Three clustering algorithms, namely, RObust Clustering using linKs (ROCK) and K-medoid, K-medoid with differential evolution (DE) optimisation algorithm are used. Based on the results, water model experimental cases are designed. A 0.4-scale water model has been employed to investigate the interactive effects of the operational parameters including, submerged entry nozzle (SEN) immersion depth, partial clogging of SEN ports, water flow rates, with both single and multiphase flows. The integral effects of the operational parameters on vortex characteristics such as size, rotation and frequencies are analyzed. Additionally, the interaction of ascending air bubbles with vortices is explained.

Three-dimensional computational investigations of the vortexing at the meniscus are performed with multiple turbulence models and the numerical predictions are compared with experimental findings. The transient vortex flow characteristics such as formation, expansion (and sustenance), thinning, merging and dissipation of the rotational flow are also predicted by the numerical simulations. The experimental and numerical findings are reconciled with the analysis of validation data set having mould powder entrained slivers only. Finally, the harmful operating parameters that promote vortexing at the mould meniscus are established.

Keywords: Continuous Slab Casting; Water model experiments; Vortex at the meniscus; URANS turbulence models; clustering techniques