SUCCESS STORY

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K1-MET
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Programme line: COMET-Centre (K1)

Type of project: P4.1 “Tundish and mold modelling”, 2019-07-01 to 2023-06-30, multi-firm

INCLUSION BEHAVIOR AT STEEL-SLAG INTERFACE

RESOLVED SIMULATIONS ON INTERFACIAL PHENOMENA IN INCLUSION RE-MOVAL

Motivation

Steel cleanliness directly affects the quality of final products, and it is a demanding task in steelmaking to achieve this. A control strategy in cleanliness is removing non-metallic inclusions (NMIs) from molten steel and transferring them into the slag covering the steel bath in the tundish (see Fig. 1). As an intermediate stage in the removal process, inclusion separation at the steel-slag interface not only affects the subsequent dissolution kinetics but is also closely related to phenomena, such as inclusion re-entrainment, which could lead to secondary steel contamination. However, this interfacial phenomenon has been either simply neglected, or improperly estimated by neglecting meniscus formation during capillary actions between the micro-sized particle and the fluid interface. Thus, a better understanding of inclusion–steel/slag interactions at the interface is essential to steel cleanliness control.

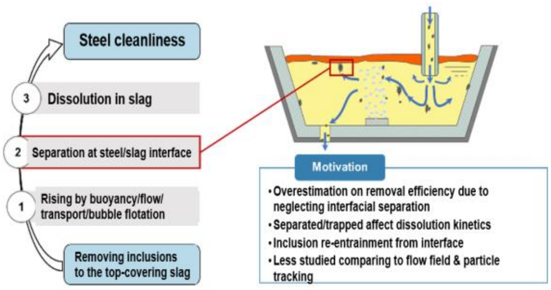

Figure 1: Schematic diagram of inclusion removal by slag absorption in industrial tundish. (Source K1-MET/JKU Linz)

Investigation

The present study focuses on the dynamics of a spherical inclusion particle interacting with the steel-slag interface. It is numerically investigated using the volume of fluid (VOF) method in combination with the overset grid technique to account for particle motion. As shown in Fig. 2, the simulations are able to reproduce the detailed particle motion close to the steel-slag interface and successfully capture the evolution of the meniscus. Besides, a sensitivity analysis on various parameters of the three-phase system is conducted to reveal the mechanisms of interfacial separation. Moreover, dimensionless numbers, such as the Weber number (We), and the capillary number (Ca) enable a prediction of whether a particle is separated into the slag or captured by the interface. All simulation results are depicted in Fig. 3.

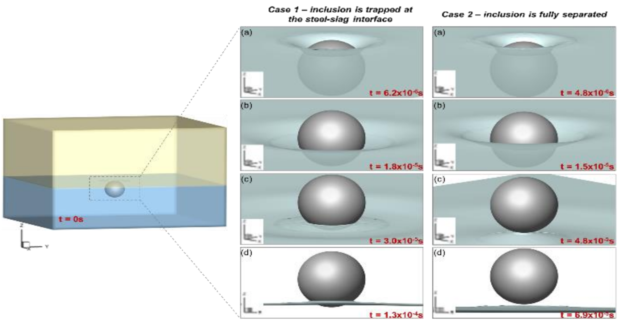

Figure 2: Evolution of particle motion across the steel-slag interface at a three-phase contact angle of 40° (Case 1) and 20° (Case 2). (Source K1-MET/JKU Linz)

Outcome and implications

The novelty of this study lies in the resolved simulations of particle behavior in the vicinity of a fluid-fluid interface. On the one hand, it provides a clear insight into the mechanism of inclusion separation at the steel-slag interface, and specifically, how the wetting condition and slag viscosity affect this process. On the other hand, the developed criterion provides a removal boundary condition to estimate the removal rate in the refining and continuous casting processes.

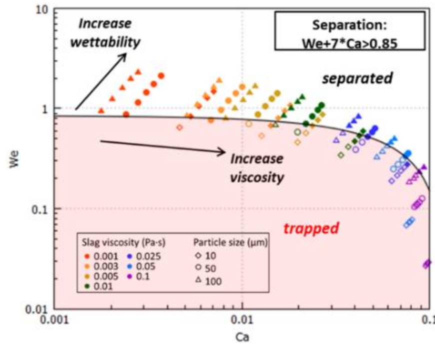

Figure 3: Phase diagram of particle behavior plotted in We vs Ca. The solid black line (We+7*Ca=0.85) is the threshold above which the particle is separated into the slag. (Source K1-MET/JKU Linz)

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Project coordination (Story)
Xiaomeng Zhang, M. Sc.
PhD Researcher
K1-MET GmbH
xiaomeng.zhang@k1-met.com

K1-MET / COMET-Project 4.1 «Tundish and mold modelling»
K1-MET GmbH
Stahlstrasse 14
4020 Linz, Austria
T +43 (0) 732 6989 75607
office@k1-met.com
www.k1-met.com

Project partners

- voestalpine Stahl, AT
- voestalpine Stahl Donawitz, AT
- RHI Magnesita, AT
- Johannes Kepler University Linz, AT
- Montanuniversitaet Leoben, AT

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