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Integrated Numerical and Experimental Analysis of Refractory Erosion: A Case Study on Alumina with CAS and CASM Slags

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Erosion in refractories plays a dominant role in the wear of these materials which is of significant relevance to the metallurgical industry. Not only is the lifespan of these materials affected by erosion but also steel quality can be reduced through the introduction of exogenous inclusions. In their application these materials are exposed to aggressive melts and intense flow conditions. The infiltration and internal corrosion of the refractory weakens the matrix-grain bonds and facilitates grain erosion under applied flow shear forces. To comprehensibly understand and characterize the erosion process, a computational fluid dynamics model was developed. In this model, the flow field of the corrosive melt is resolved and the refractory represents a dynamic boundary to the simulation domain. The erosion rate is based on a function of the applied shear stress, characterized by three erosion parameters: detachment rate, critical shear stress and an exponent. The dynamic behavior of the boundary is governed by this law and is applied through user defined functions to the refractory nodes according to the calculated erosion rate while the mesh quality is maintained through additional automated smoothing and remeshing methods. Coupling of the model to experimental finger test is used to inversely calculate the unknown erosion parameters. Experiments with coarse grain alumina samples with slags in the calcia-alumina-silica (CAS) system and calcia-alumina-silica-magnesia (CASM) were performed at temperatures of 1450 and 1500°C. Cylindrical samples were immersed in isothermal slag baths and rotated at constant speed. Next, the eroded surfaces were laser scanned and the obtained raw data processed into an axisymmetric erosion profile. These profiles are compared to the simulated erosion profiles in an automated calculated routine, where the erosion parameters are obtained as solution to the nonlinear least-squares problem. The results showed the suitability of the model in depicting the erosion of refractories within the investigated systems, revealing reasonable tendencies in the calculated erosion parameters. The detachment rate was notably higher for CASM slags due to higher degree of basicity, and increased with temperature. Conversely, the critical shear stress, an indicator of the minimum forces necessary for erosion, decreased with rising temperature, aligning with expectations. These findings emphasize the applicability of the presented method in further exploring refractory erosion in different melt systems.

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