Abstract

The main objective of this dissertation scientific work was to develop and experimentally validate a three-dimensional, multiphysics numerical model describing the behavior of molten slag during the copper recovery process in an electric resistance-arc furnace. The research focused on the copper droplet sedimentation stage, where hydrodynamic conditions and the temperature of the slag bath are of key importance. In order to validate the model, experiments were conducted on a pilot-scale two-electrode furnace installation, which required the development of an innovative, indirect method for estimating the very slow slag flow at extremely temperatures reaching 1400°C. This method was based on measuring the hydrodynamic force of the liquid on a submerged heat-resistant steel probe using a torque meter, which was supplemented by continuous measurements of electrical parameters as well as the temperature of the slag and refractory lining. The developed model coupled electromagnetic phenomena, such as Joule heating and Lorentz forces, with hydrodynamics and heat transfer, enabling the simulation of flow and temperature distributions for various electrode immersion variants. The results obtained from the simulations showed very good agreement with the experimental data, confirming the reliability of the model. The research proved that the slag flow is fully laminar and is driven mainly by natural convection, with the most intensive flow occurring near the electrodes, while undesirable stagnation zones form away from them. Finally, it was demonstrated using the validated model that that although changing the frequency of the power supply current does not affect the hydrodynamics of the system, optimizing the arrangement of the electrodes allows for an increase in the average slag mixing speed by up to 60%, effectively reducing areas of low flow dynamics.