Data-Driven Insight into Ball Mill Scaling

Błażej Doroszuk

Abstract

Ball mills play a crucial role in the mineral processing industry, but optimizing their performance and scaling up operations remains challenging. This thesis aims to gain insights into the scaling of ball mill operations by investigating the influence of operational parameters on milling performance and energy efficiency across different mill diameters. The research leverages advanced modeling techniques, such as the Discrete Element Method (DEM) and Smoothed Particle Hydrodynamics (SPH), coupled with experimental methods and a Design of Experiments (DoE) approach to develop a comprehensive understanding of the scaling process.

A systematic methodology is developed for calibrating a digital twin of a laboratory ball mill by integrating DEM-SPH simulations with experimental data from video recordings. The calibrated digital twin is then utilized in a multivariate analysis of copper ore milling, focusing on the impact of operational parameters such as mill diameter, filling degree, rotational speed, lifter size, lifter numbers, and slurry properties on key performance indicators.

A novel scaling constant is proposed and evaluated as a potential parameter for maintaining similar milling performance across different mill scales. The results reveal that maintaining the scaling constant at a comparable level results in a consistent degree of energy utilization per unit mass per rotation in dry and wet milling conditions.

A Design of Experiments (DoE) approach is employed to investigate the main effects and interactions of the studied factors on mill performance metrics for both dry and wet milling series. The DoE results provide valuable insights into the most influential parameters affecting ball mill efficiency and product quality.

Correlations between mill diameter, operational parameters, and performance metrics are identified and quantified in both dry and wet milling environments to guide the development of scale-up strategies. The insights gained from this study contribute to the understanding and optimization of ball milling processes, laying the foundation for developing energy-efficient and sustainable mineral processing strategies with specific implications for the Polish copper mining industry.

The thesis concludes by providing recommendations for future research directions, focusing on refining the scaling constant approach and potential tests that can be performed on industrial-scale copper ore mills to improve efficiency. The findings of this research can inform the design and operation of ball mills across different scales, ultimately leading to improved productivity, profitability, and environmental sustainability in the mining sector.

Błażej Doroszuk