

## **Artificial Intelligence Across the Comminution Value Chain**

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Artificial intelligence (AI) is rapidly transforming the comminution value chain by unifying ore characterisation, grinding, classification and separation into a single, data-driven ecosystem. This presentation examines the evolution from isolated soft sensors for individual unit operations to plant-wide hybrid architectures that combine physics-based simulations, machine learning and, increasingly, large language models (LLMs). This presentation provides an overview of AI development in comminution, showcasing methodological innovations and recent advances that pave the way for autonomous, resource-efficient grinding circuits.

Consider, for example, the integration of sequential neural networks, a technique that has been shown to convert low-cost online measurements such as ultrasonic extinction and stirrer torque into accurate estimates of particle size distribution and time-varying suspension viscosity. To address the sparse and dynamic nature of process data, CFD–DEM simulations act as generators of synthetic data, revealing operational extremes and latent variables such as local stress intensity. These datasets support grey-box hybrid models, where mechanistic simulations are enhanced by physics-informed AI frameworks that become increasingly interpretable through symbolic regression. A recent development in this field is the integration of transformer-based LLMs with mixture-of-experts (MoE) frameworks. These frameworks translate natural language queries into actionable simulation or control tasks. They facilitate retrieval-augmented reasoning over technical documents and orchestrate multi-step computational workflows via autonomous software agents.

Together, these technologies enable core capabilities such as uncertainty-aware sensing, adaptive model-predictive control and explainable hybrid modelling, as well as human-in-the-loop autonomy. Their integration creates a robust digital infrastructure that can respond to ore variability, stricter product specifications, and the need for greater energy efficiency. This keynote will illustrate these developments through selected case studies and highlight future directions for AI-enabled comminution systems.