Data-Driven Approaches To Dynamic Optimization

THE UNIVERSITY OF BRITISH COLUMBIA

Bill Tubbs | Sanja Miskovic | University of British Columbia - Norman B. Keevil Institute of Mining Engineering

Question

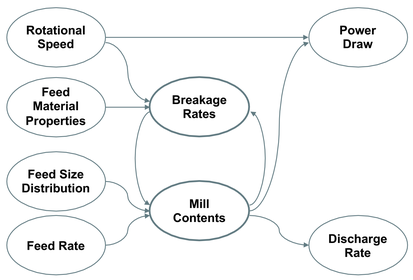
How can we operate a SAG mill at optimal conditions–high throughput and grind performance when the ore feed is constantly changing?

Motivation

- The grinding process has complex, non-linear dynamical behaviour.
- Important process variables are not measurable.
- High variability in ore properties makes online optimization difficult.
- Current models do not capture all the dynamics.
- The industry needs a systematic approach to mill performance analysis and real-time optimization that is implementable at sites.

System Dynamics

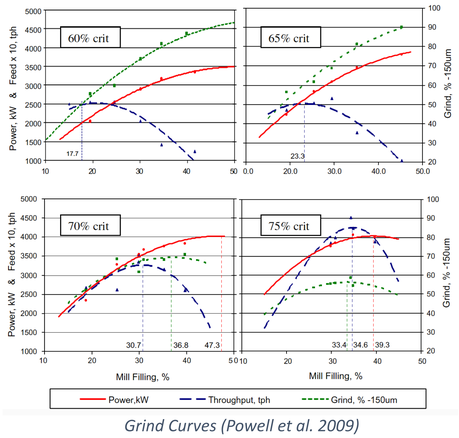
- To optimize a process we need to identify the system dynamics.
- The interaction between mill contents and breakage rates is key to grinding performance and throughput.



Cause-Effect Relationships Between Main Process Variables

Previous Work

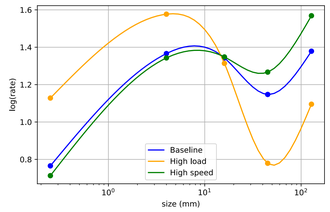
- Steady-state mill tests reveal the complex relationships between process variables.
- Throughput, power, and grind curves peak at different fill levels.
- The shape of the grind curves is dramatically affected by mill speed
- Grind curves depend on ore properties (Powell et al. 2009).



Grind Curves (Powell et al. 2009)

Population Balance Model

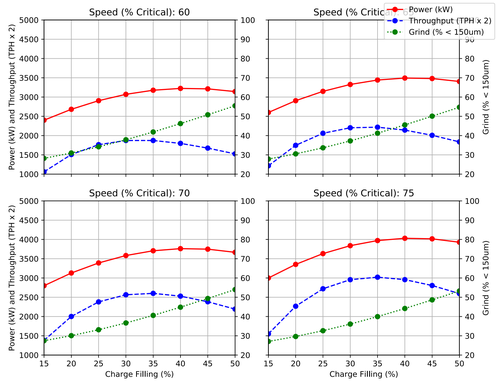
- We implemented a population balance model with a dynamic breakage rate based on empirical results from Morrell et al (2004).
- Our SAG mill simulator is based on the Molycop Tools models
  - Open circuit
  - Closed circuit with pebble crushing
  - Closed circuit with pebble crushing and hydro-cyclones



Effect of Mill Load and Speed on Breakage Rates (Morrell, 2004)

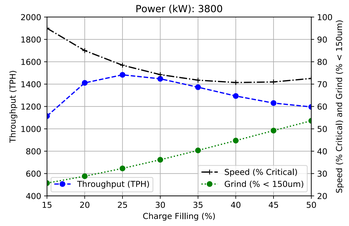
Simulation Results

- Steady-state Simulations show that throughput and power peak at different fill levels.
- Grind performance increases with fill level.
- Optimum fill level varies only slightly with speed.

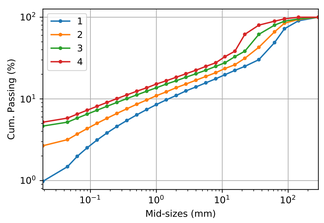


Simulated Grind Curves

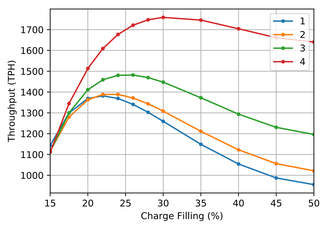
- Grind curves constrained by maximum power provide insights into actual operating limits.
- We are interested in the effect of changing feed properties on throughput and optimum filling and speed.



Simulated Grind Curves

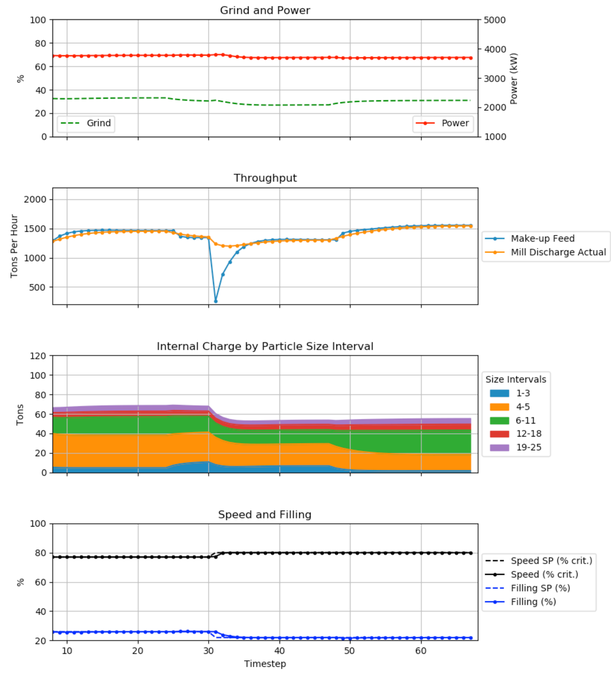


Different Feed Size Distributions



Effect of Feed Size on Maximum Throughput at Maximum Power

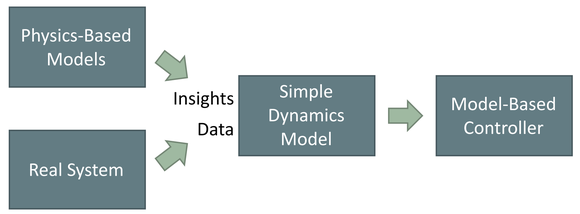
Dynamic Optimization



Hypothesis

- Data-driven optimization techniques can potentially 'learn' complex system dynamics from observed data.
- However, model-based methods are more robust, easier to interpret, and do not require impractical amounts of operating data.
- With model-based methods and a data-driven approach we can improve on the performance of an experienced human operator.

Data-Driven Approach



Data-Driven Approach to Model-Based Optimization