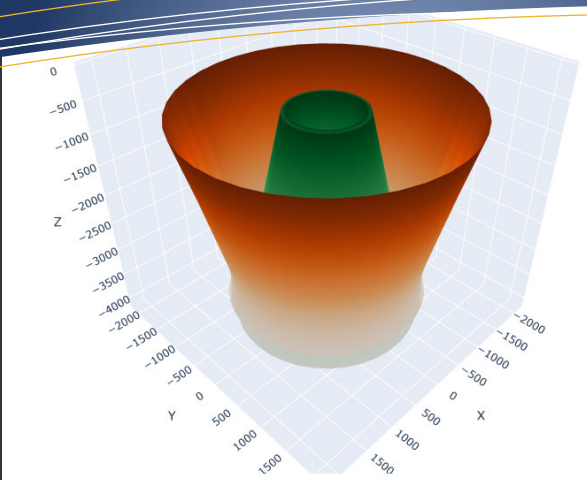
Kinematic Crusher Model (KCM)



A comprehensive model to optimize cone and gyratory crusher performance

Crushing Studies Enabled by KCM

- Troubleshooting and analysis of crushing plant performance;
- Equipment design and performance assessment;
- Operational debottlenecking and process plant optimization;
- Investigations of premature eccentric bush failures;
- Liner redesign to extend life and maintain throughput;
- In-Pit Crushing and Conveying (IPCC) studies;
- Studies for crushing plants and flowsheets, including modelling and simulation;
- Technical due diligence for equipment and systems;
- Advanced mine to product and plant simulation using dynamic and steady-state models;
- Proof of concept engineering, evaluation and testing of innovative equipment and processes.

Enhancing crusher performance

Overview

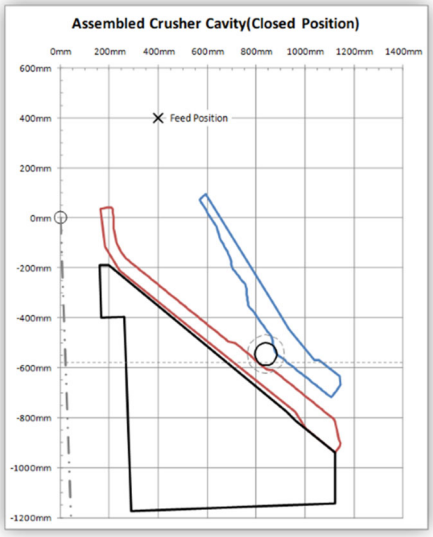
In 2009, Bear Rock Solutions, in collaboration with Met Dynamics, developed the Kinematic Crusher Model (KCM)—a sophisticated tool for simulating and optimizing gyratory and cone crushers. This model integrates a mechanical representation of the crusher with the breakage characteristics of the feed material, enabling detailed analysis of both process performance and the mechanical response of the crusher system.

KCM has been successfully applied at operations around the world, consistently delivering significant value by improving equipment design, process efficiency, and liner performance.

Model Description

Building on the work of Bearman, Briggs, and Evertsson, KCM combines:

- Accurate crusher chamber geometry;
- Particle motion equations;
- Population balance breakage model.



Together, these enable predictions of key performance and mechanical parameters, including:

- Product size distribution
- Power consumption
- Energy distribution within the chamber
- Hydraulic pressure
- Onset of packing and power overload
- Liner wear profile

Bear Rock Solutions

Met Dynamics

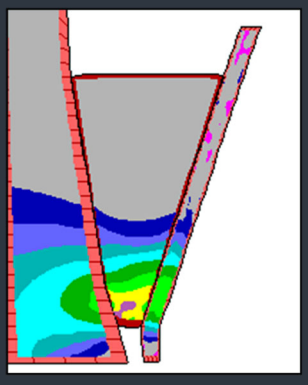
The most difficult crushing duties

KCM is designed to accurately and realistically address rock crushing duties, even with the most extreme strength feed.

On occasions, compression crushers are pushed even further, with the introduction of fine, or high clay feed.

In such cases KCM is combined with the Compaction Stress Modelling method. Using this approach BRS can examine how fine, sticky materials flow through a compression crusher and the degree of compaction that takes place.

By assessing compaction down the length of the crushing chamber, the crushing forces can be evaluated and this knowledge can be used to examine ethe crusher variables and liner profiles.



Changes to the crusher and liners have been used to overcome throughput and crushing force issues, in such circumstances.

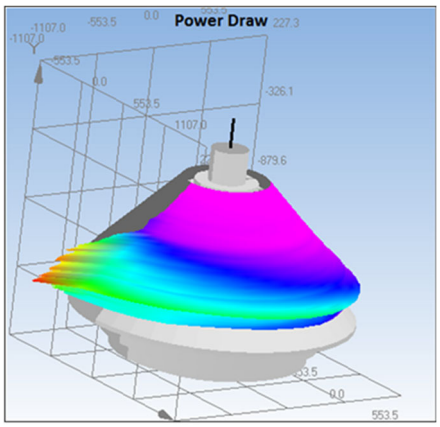
Crushing is all about the effective distribution of energy

KCM allows us to understand the internal processes inside the crusher in a unique and highly valuable way

The model accepts inputs such as:

- Mantle and concave liner geometry
- Closed Side Setting (CSS)
- Eccentric throw and speed
- Feed rate, size distribution, and feed strength

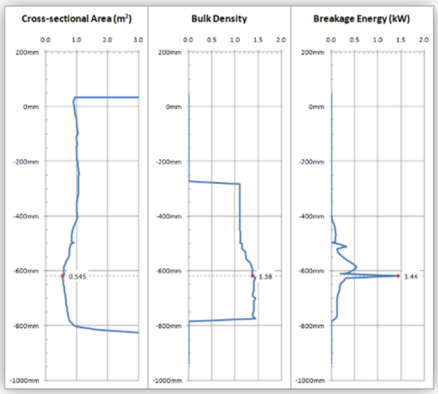
With these, KCM delivers a detailed and predictive view of crusher performance under varying operating conditions.



Diagnostic Capabilities

KCM produces a range of insightful diagnostic outputs that extend beyond conventional performance metrics. These include:

- Identification of the choke point in the chamber
- Changes in bulk density throughout the crushing process
- Distribution of crushing power within the chamber
- The liner's ability to nip, accept, and break feed at various chamber locations.



Performance Outputs

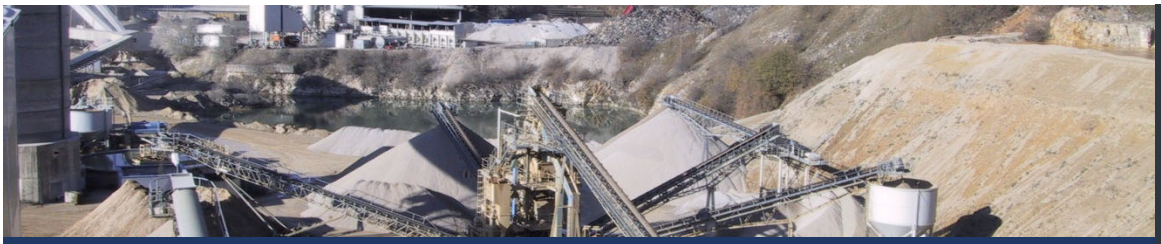
Alongside advanced diagnostics, KCM also provides traditional KPIs such as:

- Product size distribution
- P80
- Throughput
- Power draw
- Crushing force

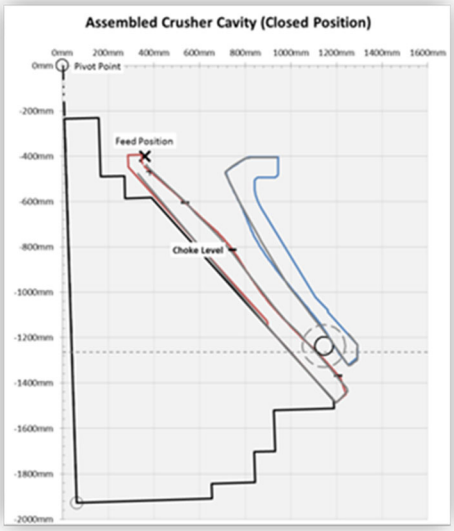
Liner Wear Modelling

A powerful feature of KCM is its ability to predict liner wear profiles over time and tonnage. Liner wear significantly affects both performance and mechanical loading, and its accurate prediction is crucial for optimization. In validated case studies, KCM's wear predictions have shown high correlation with measured data. This capability has enabled:

- Optimized liner design to extend service life
- Avoidance of issues like ring bounce caused by poor wear profiles late in liner life.



Considering the entire flowsheet

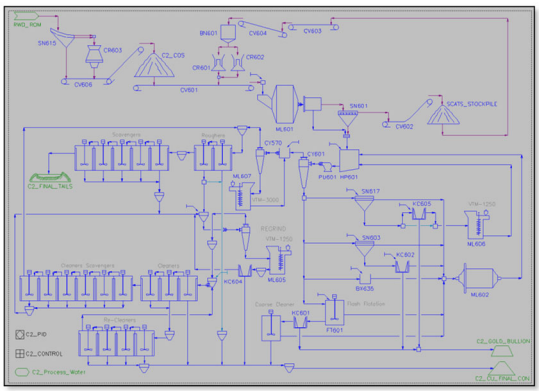


Integration with Flowsheet Models

KCM is fully integrated into the SysCAD flowsheet simulation platform enabling:

- Steady-state and dynamic simulation of crushing circuits
- Seamless integration with Met Dynamics' existing suite of customized crushing, grinding, and classification models

This integration supports complex flowsheet analysis and optimization, helping clients make data-driven decisions across entire processing circuits.



Example Applications

KCM has been applied to a wide range of real-world scenarios, including:

- Optimization of pebble crushing to increase SAG mill throughput
- Improved cone crusher feed preparation for HPGR circuits
- Balanced multi-stage crushing for iron ore and aggregates
- Integration of block cave fragmentation through to beneficiation

Model Availability

The Kinematic Crusher Model is currently available for use in consulting projects via Bear Rock Solutions and Met Dynamics. KCM provides a robust, independent approach to crusher optimization, with benefits including:

- Improved process performance
- Reduced operational downtime
- Extended liner life
- Improved reliability from key components
- Enhanced energy efficiency across circuits

Whether for greenfield design or brownfield improvement, KCM offers a powerful foundation for data-driven crushing optimization.

Additionally, KCM can also be used as:
Basis for a “soft-sensor” system for real-time crusher control
As the comparative reference base-case for mechanical prognostic analysis, i.e. estimating probability of failure in key components.

Adding experience to modelling

Even the best models benefit from the input of experienced consultants and personnel.

Creators and developers, Dr. Ted Bearman and Scott Munro are both closely involved with any simulations and offer perspectives shaped by their experience – see following biographies.

Dr. Ted Bearman (Bear Rock Solutions) is a mining professional with 38 years’ experience including crusher design, flow sheet optimization and mechanical/process improvement of crushers. Ted’s PhD and his subsequent work, is widely credited as being the catalyst for a new wave of crusher models. e and in collaboration with Scott Munro, has developed a model that provides genuine insights into the machine-rock interaction.

Scott Munro (Met Dynamics) is an independent consultant who specializes in the simulation and modelling of mining and mineral processing systems. Scott has an innovative approach to simulation and has led the development of systems to address the interface between the various aspects of the total mining value chain. In addition, Scott has also been pivotal in the development of leading edge simulation work for ore specific process models. In his past roles Scott has held positions with Rio Tinto, CSIRO and Hatch.

Professional Development

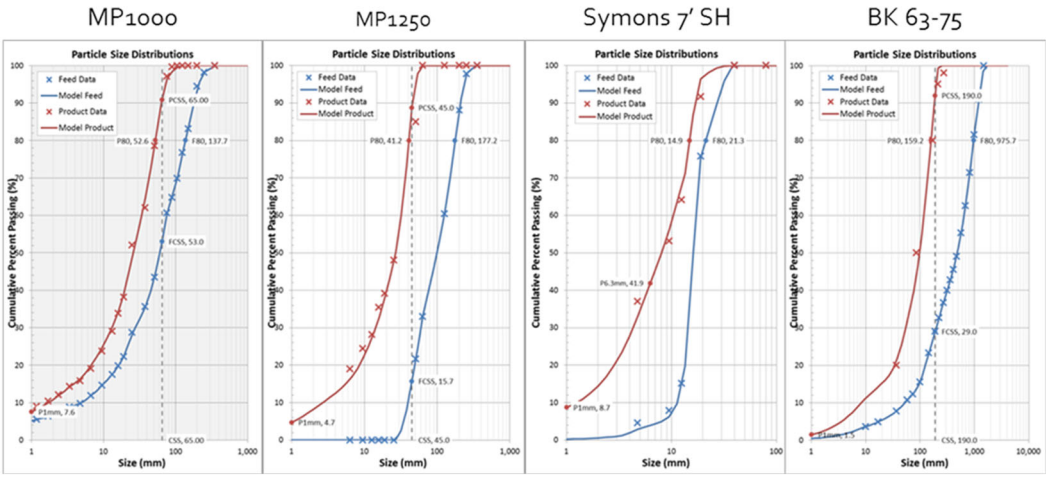
Not only does the Kinematic Crusher Model offer a tool for investigating crushing issues and optimization, but it can also be used as part of training and professional development.

Courses can be offered by Bear Rock Solutions, or alternatively via our partnership with Crushology.

Courses can be customized to suit the requirements of a particular company and this can include equipment specific modules.

Model Validation

The model has been used in numerous consulting projects and has been proven to deliver highly accurate estimates of crusher performance. The model has been used to investigate both mechanical and processing aspects of crusher performance. Comparisons of predicted versus actual product size distributions for a range of crusher types are shown below. In terms of energy distribution in the chamber, the product size is the best indicator of the accuracy of the energy predictions and therefore the model itself. The predictions seen therefore provide strong validation of the model performance.



Machines Studied

The following gyratory and cone crusher types have been successfully analyzed using KCM. For each machine type, studies have been completed for various clients, giving a total number in excess of one hundred.

- Metso: 60-110, 60-89, 54-75, 54-67, MP2500, 1250, 1000, 800, HP4, 5, 700, 800, Symons 4ft, 5.5ft 7ft (EXHD, XHD, HD)
- Svedala: 60-89, 54-74
- Sandvik/Svedala: CH870, CH890, H8800, H8000, H6000, H4000, H3000
- FLS: 63-118, 60-113, 60-89, 54-77, XL2000, 1300, 1100, 900
- ThyssenKrupp: 63-130, 63-109, 63-89, 63-75BK
- Earthtechnica: 54-75
- Terex: Automax 1300, 900
- Earthtechnica: Z1515, HPC2400

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