Mine-to-Mill Optimization

Using Mine-to-Mill Technology to Optimize Crushed Stone Production

Historically, the production of a mineral commodity has been perceived as two distinct stages: 1) mining to extract the commodity from the ground, and 2) processing to convert it into a marketable end-product. However, mining and processing are intimately linked, particularly when reducing particle size. Without considering the entire system, optimizing each stage separately often misses economic and energy-saving opportunities.

Mine-to-mill technology takes the entire system into account, from the blasting process to the comminution circuit. This optimization provides a complete fragmentation and size reduction solution to maximize benefit. The aggregates industry will serve as a test candidate to develop this system. The primary focus will be on the reduction of energy consumption in the aggregate production process.

Researchers at Virginia Polytechnic Institute and State University, along with their project partners, are looking at mine-to-mill technology to effectively optimize the production of crushed stone. A general purpose blasting simulation package (JKSimBlast) will be used to evaluate blasting performance. Blasts can be analyzed and evaluated for energy, scatter, vibration, fragmentation, damage and cost. The JKSimBlast package incorporates an explosive selection tool containing fragmentation and muckpile shape prediction models. The models predict the size distribution from different blast designs in the same material.

The aggregate plant operation is simulated through the use of the JKSimMet program. JKSimMet incorporates mathematical models of crushers and screens to represent the processing steps which occur after blasting. In the crusher models, feed is considered to undergo a series of breakage and classification stages as it passes down the crushing chamber. The open and closed side settings control classification in the chamber of the crusher.

If the rock is larger than the open side setting (OSS) then it will remain in the chamber and be broken. Conversely if the rock is smaller than the closed side setting (CSS) it will fall out of the chamber and not be crushed any further. For rocks that are in between the CSS and OSS in size, a probability function is used to determine if they will remain or pass out of the crusher.

Screening is modeled using the standard S-shaped efficiency curve that one normally encounters for a screening operation. In the JKSimMet simulator screening efficiency is primarily related to the feed rate per unit width of screen. The simulator also incorporates different relationships for rubber and steel screen decks. Finally, the model incorporates a fines factor to describe the "piggyback" effect of fines adhering to coarse material.

A typical mine-to-mill optimization effort includes four steps: (i) scoping study, (ii) analysis, (iii) optimization, and (iv) implementation. The scoping study consists of a site visit to review current mining and processing practices and discover possible areas for improvement. The analysis step involves a detailed survey of all aspects of a mining operation from blasting to crushing and screening. Rock domains are identified and rock mass characteristics are determined. Samples are collected around all crushers and screens under a variety of operating conditions in order to obtain information for use in the JKSimBlast and JKSimMet models. Once all aspects of a mining operation are analyzed, the data collected from the analysis step are used in the optimization step in conjunction with the JKSimBlast and JKSimMet computer packages to optimize the mine and plant operating strategies. Finally, the most promising strategies identified during optimization are used to improve total system performance.

Benefits for Our Industry and Our Nation

- *Increases throughput by 10%.*
- *Reduces excess fines that result from crushing operations.*
- *Reduces energy consumption by 10% in mine-to-mill activities.*
- *Reduces greenhouse emissions by reducing use of explosives.*

Applications in Our Nation's Industry

The aggregates industry, representing the largest segment of the U.S. mining industry, will benefit the most from mine-to-mill technology, focusing on particle size control rather than particle size reduction. Optimization of all size reduction operations could also reduce explosive use in mining industry operations, resulting in a reduction in greenhouse emissions from blasting.

Project Description

Objective: To develop a mine-to-mill optimization technology as an effective tool for the reduction of energy consumption in the U.S. mining industry, by first examining the aggregates industry.

Two computer programs, JKSimBlast and JKSimMet will be used to simulate blasting operations. These simulations will be used in conjunction with cost and energy data to optimize the operations. The most promising mining alternatives will be implemented onsite and a detailed sampling campaign will be conducted, evaluating and quantifying energy and cost savings.

Virginia Polytechnic Institute and State University will be the project manager for this effort, with Contract Support Services/JKTech providing mine-to-mill expertise, Luck Stone Corporation as the mining company providing two test sites for the work, Austin Powder as an explosives service provider with expertise in blasting, and Mellott Enterprises, Inc. as an equipment supplier to the aggregates industry providing crushing and screening expertise.

Results

The blasting and processing plant at Pittsboro were successfully modeled based on blast design variables, rock properties, and other detailed analysis of comprehensive plant audit data collected. The predicted Run-of-Mine (ROM) fragmentation appears in line with image analysis results obtained in the field. These models were used to investigate a range of new blast design recommendations aiming to reduce the amount of +150 mm, especially oversize, while not increasing the percent crusher run (-38 mm) significantly.

Plant Sampling at Luck Stone's Bealeton Quarry

On the basis of simulations, there is scope to increase the primary and secondary production rates with a small reduction in the overall energy consumption by changing the blast design according to the guidelines drawn up in consultation with Luck Stone. The modified blast designs should increase the primary throughput by 15% and secondary by approximately 6%, with an overall specific energy reduction of around 1%. The resulting base fraction in the ROM is expected to increase by 2% from 36% to 38%. The secondary plant feed size will be finer, resulting in a lower circulating load around the crusher. Though the net yield to the tertiary plant is expected to reduce on account of the increased base fraction in the ROM, the rate of tertiary feed production will increase. The tertiary plant performance and product yields are not expected to change. The impact of the new ROM fragmentation on the Bivtec will need to be closely monitored, particularly if the secondary feed rate is significantly increased and the feed becomes very fine.

Commercialization

The commercialization plan for transferring Mine-to-Mill® technology to the aggregate industry includes:

- Training for Luck Stone personnel (two sessions completed as of March 06)
- Presentations at national meetings on the case studies resulting from this project (three presentations made)
- Publications in aggregate trade journals on the case studies resulting from this project (seven as of August 2005)
- Short courses on Mine-to-Mill® technology for the aggregate industry to be held at Virginia Tech and other venues
- Attendance of Contract Support Services/JKTech as vendors at key aggregate trade shows

Project Partners

Virginia Polytechnic Institute and State University
Blacksburg, VA

Austin Powder
Cleveland, OH

Luck Stone Corporation
Richmond, VA

Mellott Enterprises, Inc.
Warfordsburg, PA

Contract Support Services
Red Bluff, CA

JK Tech
Queensland, Australia

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

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