Optimization of Comminution Circuit Throughput and Product Size Distribution by Simulation and Control

Quarterly Technical Progress Report

Reporting Period Start Date: April 1, 2001
Reporting Period End Date: June 30, 2001

Authors: S. K. Kawatra - Principal Investigator
T. C. Eisele - Engineer/scientist
H. J. Walqui - Graduate Student

Date of Issue: December 2001

DOE Award Number: DE-FC26-01NT41062

Submitting Organization:

Department of Mining and Materials Process Engineering
Michigan Technological University
1400 Townsend Drive
Houghton, MI 49931-1295

Abstract

The goal of this project is to improve the energy efficiency of industrial crushing and grinding operations (comminution). Mathematical models of the comminution process are being used to study methods for optimizing the product size distribution, so that the amount of excessively fine material produced can be minimized. This will save energy by reducing the amount of material that is ground to below the target size, and will also reduce the quantity of material wasted as "slimes" that are too fine to be useful. This will be accomplished by: (1) modelling alternative circuit arrangements to determine methods for minimizing overgrinding, and (2) determining whether new technologies, such as high-pressure roll crushing, can be used to alter particle breakage behavior to minimize fines production.

In the second quarter of this project, the model completed in the first quarter was validated to ensure that it could predict accurately the performance of a mill grinding a realistic distribution of feed particles. Validation was successful. Sampling and data collection were also begun at the plants operated by the industrial co-sponsors of this project.

Table of Contents

List of Graphical Materials

Introduction

Crushing and grinding (comminution) of various feedstocks is a critical operation in mining, as well as in a range of other industries. However, comminution is both energy-intensive and expensive, with tremendous room for improvement. A neglected route in optimizing the comminution process is the minimization of overgrinding. Since grinding particles to finer than the target size both wastes energy and produces unusable product, such overgrinding must be minimized in order to improve energy efficiency.

Optimization of full-scale comminution processes by direct experiment is difficult and expensive because of the cost of modifying and operating the circuits to conduct these experiments. Mathematical simulation of the process is therefore necessary in order to make a preliminary determination of the most promising routes for optimizing the processes. The research needed to develop the models will also determine what effects can be used to alter not just breakage rate, but also the manner in which breakage occurs, and to use this information to improve control over product size.

Executive Summary

The goal of this project is to use comminution modelling to study methods for optimizing the product size distribution, so that the amount of excessively fine material produced can be minimized. This will be accomplished by: (1) modelling alternative circuit arrangements to determine methods for minimizing overgrinding, and (2) determining whether new technologies, such as high-pressure roll crushing, can be used to alter particle breakage behavior to minimize fines production.

In the first quarter of this project, a mathematical model was completed and implemented as an Excel spreadsheet. The model is applicable to two classes of comminution machines that are widely used in industrial practice:

- A Roll mill, consisting of two counter-rotating steel rollers with variable spacing, and
- A Ball mill, consisting of a cylindrical shell filled with steel grinding media.

In the current quarter, validation of the model results against results from actual comminution testwork was completed. The model successfully predicts the product size distribution from a pulverization process, based on mill settings and feedrates.

Project personnel met with professional staff an the Cleveland Cliffs Iron Co. to plan plant studies. These studies will include sampling of the grinding circuit of an operating iron ore concentrator, thorough analysis (chemical and physical) of plant products, and analysis of historic data collected from the concentrator. Project personnel also worked with personnel from J. M. Huber Inc. and Badger Mining Co. to develop details of the research plan, and to prepare samples and plant operating data from their respective operations.

Experimental

The model completed in the previous quarter was validated by preparing feeds of known particle size, passing them through the laboratory grinding process, and comparing them with the results predicted by the comminution model. The feeds examined were prepared by making a synthetic mixture of the monosized feeds that had been used to determine breakage and selection functions.

Results and Discussion

Two examples of predicted particle size distributions are presented in Figure 1 using the pulverizer model developed to date in this project. The curves represent cumulative percent of the weight of the material that is coarser than a particular size.

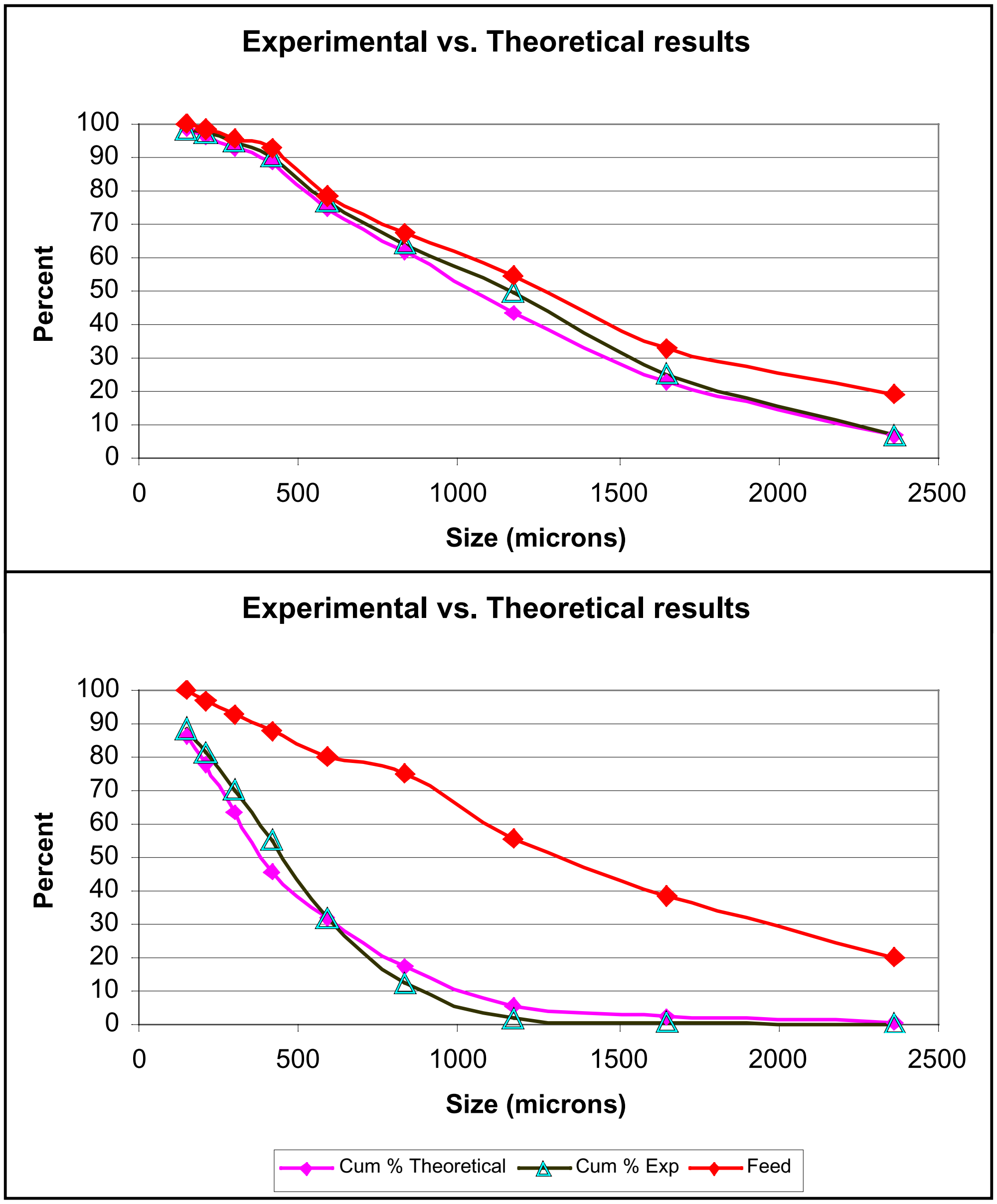

Figure 1: Comparison of comminution results predicted by the model (Cum % Theoretical) with actual performance of a comminution device (Cum % Exp), for two different feed sizes and two sets of machine operating settings.

The red curve is the size distribution of the feed, the purple curve is the predicted product size distribution, and the black curve is the actual product size distribution as determined by experiment.

The upper graph represents the results of an experiment where the pulverizer was set to produce a coarse product, and therefore there was relatively little breakage occurring. The lower graph represents results when the pulverizer was set to produce a fine product, and so a great deal of breakage was occurring.

In both cases, the product size distribution predicted by the model was in very close agreement with the actual product as determined by experiment, showing that the model can accurately predict product size distributions based on pulverizer operating conditions.

Planning of plant sampling procedures for the next step of the project is currently underway.

Conclusions

The model completed in the first quarter has been successfully validated, and the model and procedures developed will be applied to the plant studies that will be carried out in the remainder of this project. These plant studies are currently in the planning stages.

References

Bakshi, A. K., Shoop, K. J. and Kawatra, S. K., "Changes in Autogenous Grinding Performance due to variation in Slurry Rheology", Proc. of Autogenous and Semiautogenous Grinding Technology, University of British Columbia, Vancouver. Vol.1, 1996, pp 361-372.

Herbst, J. A., and Pate, W. T. (1998), "Dynamic Simulation of Size Reduction Operations from Mine to Mill", Australasian Institute of Mining and Metallurgy Publication Serie43s No. 4, pp. 243-248

Napier-Munn, T. J., Morrell, S., Morrison, R. D., and Kojovic, T. (1996) Mineral Comminution Circuits: Their Operation and Optimization, Julius Kruttschnitt Mineral Research Centre, Indooroopilly, Queensland, Australia

Shoop K. J. and Kawatra, S. K., "Effect of Rock Breakage Characteristics and Fines/Clay Content on the Autogenous Grinding of Iron Ore", accepted for publication, 1995.

Shoop, K. J. and Kawatra, S. K," Effect of Rock Breakage Characteristics and fines/clay content on the Autogenous Grinding of Iron Ore" Minerals and Metallurgical Processing, Vol. 13, No.1,1997, pp 14-21.