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Progress Reports

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Affiliate Projects

0642 "Enhanced Efficiency of Comminution Processes"
University of California at Berkeley

This project has been completed and a final report was submitted during the last reporting period.

II. FINANCIAL STATUS REPORTS

Utah Breakdown
Composite

1998 1st Semiannual Progress Report

Subaccount 4920

Grant #G1155249

"Administration and Reference Center"

1995 - 1998

R. P. King - Account Executive

Objective

The goal of the Center office staff is to provide support to all research projects, including administrative, secretarial and technical support and to extend and maintain the Communion Reference Center.

The purpose of the Communion Reference Center is to gather relevant communion literature into one place, to centrally locate research materials and data and to continually upgrade and generate new materials and sources of past, present and future developments in the technology and understanding of communion.

Approach

The office is providing assistance in preparation of reports, budgets, manuscripts, purchasing, travel arrangements and personnel administration.

The Reference Center provides researchers quick and efficient access to current communion literature as well as interdisciplinary books and journals that are relevant to Communion Center research projects.

Progress

The holdings of the Reference Center have been increased to the following at the end of the review period: 3,825 reprints, 108 theses, 465 books and 5 video tapes. New acquisitions are cataloged electronically and all existing items are indexed and abstracted in machine readable form. The abstracts are available on WordPerfect files, which allows printing of the full text including complex mathematical text and special symbols. All abstracts can be searched by keywords and word groups. Information retrieval is accordingly efficient. Lists of all acquisitions – reprints, books and theses – for the reporting period are available on request from the Reference Center.

The most significant progress recorded during this reporting period has been the continuing interest in the database as shown by the number of specific remote searches conducted on the Reference Center database. The database can be accessed and searched from remote computer sites using readily available software such as Mosaic, Netscape and Internet Explorer. The WWW address of the Reference Center homepage is <http://www.mines.utah.edu/~wmuucc>. The web site has received an average of 2,773 visitors per month during the six months of the reporting period. In addition, an average of 219 searches per month has been conducted in the database via the World Wide Web. The activity on the home page is shown in the graph.

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Subaccount 4939

Grant #G1155249

"Optimal Energy Utilization Strategies for Comminution"

1995-1998

S. Middlemiss - Graduate Student

R. P. King - Principal Investigator

Objective

The objective of this project is the investigation of methods by which impact energy can be used more efficiently for comminution and to develop methods for the practical application of low-energy comminution devices.

Approach

The approach that is taken relies on very careful experimental procedures to determine the fundamental fracture properties of brittle particulates. Three experimental techniques have been developed in the Comminution Center and are the primary sources of basic data. These are: the ultrafast load cell for the measurement of particle strength and the distribution of particle fracture energies; the dual impact load cell, which provides information on the effect of internal damage both predamage due to various pretreatments and damage that accumulates during the very rapid impact events; and indentation fracture, which provides measurements of the microscale morphology of crack development in brittle mineralogical materials and a quantitative estimate of the fracture toughness. These three characteristics are believed to characterize the energy consumption processes during individual particle fracture. Optimal energy application strategies will be determined using the quantitative characterization of particle breakage with respect to impact energy.

Progress

Research has been completed and a dissertation is currently being written, which is expected to be completed before the next reporting period. Results show that non-random breakage in binary mineral ores can take place in a number of different ways, each with its own characteristics. Examples of some of these are:

- grain boundary fracture resulting in increased exposure of both mineral phases - e.g. IOC Magnetite Hematite),
- preferential breakage of one phase (resulting in increased exposure of one phase over the other e.g. Taconite),
- breakage phenomena that depend on the microstructural scale (resulting in preferential breakage of large microstructural domains over smaller ones, with a consequent change in material texture e.g. Falconbridge Ni-Cu matte).

Experimental results also show that there are a number of energy dissipating mechanisms operating that contribute to reduced fracture efficiency in comminution, such as crack deviation from a planar path and crack bifurcation and arrest as a consequence of the microstructure.

More research will be required in the future to fully understand and model the complex interactions between material microstructure, fracture processes and resulting energy utilization during comminution.

1998 1st Semiannual Progress Reports

Subaccount 49A1
Grant #G1155249
"Ball Mill Scale-Up"
1995 - 1998

A. Datta - Graduate Student
R. K. Rajamani - Principal Investigator

Objective

Scale-up refers to the idea of designing industrial mills based on test work done on an ore sample in a laboratory mill as small as 10 inches in diameter. Conversely, predicting the steady-state operation of existing industrial grinding circuits from test work done on a laboratory mill is equivalent to scale-up.

Approach

The two subprocesses, particle breakage and particle transport in the mill, contribute to the size distribution of product in the mill discharge. In the past, scale-up of particle breakage has been done by the Bond Work Index method and better yet by the selection/breakage function model. The later model lacks the ability to account for the effect of ball sizes in particular and also the mill holdup. The current approach is based on factoring the breakage rates by the ball collision energy spectrum of the mill. Since the collision spectrum is a consequence of the magnitude of design and operating variables, the proposed scale-up accounts for all the variables in a mechanistic fashion.

Progress

The experimental part of the project is complete. That includes: a) a breakage study using the drop-ball apparatus for different sizes of limestone, ball diameter and impact energy and b) grinding tests in 10-inch, 15-inch and 36-inch batch mills. Five different sets of lifter configurations were used in a 36-inch mill while tests were conducted at three different speeds for each of them.

At this point, the following tasks are being worked on for the completion of this project:

- a) Analysis of the data from the drop-ball tests and repetition of some of the tests as a check for reproducibility.
- b) Simulation of all the grinding cases with the discrete element simulator to extract the impact energy spectra.
- c) Analysis of the merits and demerits of the model by comparing the predictions with the measured product size distribution.
- d) Establishment of a correlation between the impact energy spectra and mill product size distribution.

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Subaccount 49A3

Grant #G1155249

"Ball Media Motion Computer Code"

1995 - 1998

R. Venugopal - Graduate Student

R. K. Rajamani - Principal Investigator

Objective

In the past few years, a computer program called 2DMILL has been developed to simulate the motion of ball charge within autogenous and semi-autogenous mills. The objective of this project is to enhance several aspects of that program, including a GUI and a visualization package to view the two dimensional animations of the ball charge. The project also aims at developing a code capable of simulating three dimensional ball charge motions using the object-oriented features of C++.

Approach

Users originally ran the 2DMILL code from basic command-line interfaces that prompted the user for the required information. The newly added Visual Basic interface enables interactive user input through fill-in-the-box type forms at the beginning of each run and then processes the data accordingly. The user can prompt the program to display all the results of the run in a visual format that is easy to interpret. Maintaining the basic structure of the 2D code, a 3D code is being developed using an extension of the DEM algorithms used for simulating 2D-ball charge motion.

Progress

During this quarter, subroutines for contact force and contact detection were written. These routines include ball-ball force, ball-wall force and outside-corner force. A routine for corner detection was also developed. In addition, routines for detecting outside corner and inside corner were written.

Next, the verification of code results against actual ball mill experiments was taken up. Three mills of size (D $\times$ L) 0.25 m $\times$ 0.29 m, 0.38 m $\times$ 0.29 m, and 0.90 $\times$ 0.10 m were used in this study. The power draft predicted by the 3-D computer code agreed within $\pm 5\%$ of the measured power. Currently, work is in progress to predict the power draft of an industrial ball mill of size 4.1 $\times$ 5.96 m. The results obtained so far prove conclusively that the code is very reliable for mill power draft predictions.

Furthermore, the verification of the code predictions was taken up by actually comparing the predicted ball charge profiles against photographs of the actual ball charge in mills. To accomplish this task, the 0.90 m $\times$ 0.10 m ball mill was fitted with a clear plexiglas plate and still pictures of the cascading charge were taken. The code predicts both cascading and cataracting ball motion to a reasonable degree of accuracy.

The graduate student, Ramesh Venugopal, is currently writing his M.S. Thesis on this topic.

1998 1st Semiannual Progress Report

Subaccount 49A4

Grant #G1155249

**"Fracture of Brittle Particles in Constrained Beds
Measured on the Ultrafast Load Cell"**

1995 - 1998

L. Milin - Graduate Student

R. P. King - Principal Investigator

Objective

The objective of this research project is to use fundamental fracture data collected on the Ultrafast Load Cell (UFLC) to predict the operating behavior of ball mills under real conditions including wet and dry grinding for batch and continuous operations with a distribution of particle sizes in the mill.

Approach

This project will build on existing procedures that were developed in earlier projects at the Comminution Center, which have been shown to be accurate and effective. Single particle and particle-bed fracture tests will be carried out on the UFLC. In parallel, batch and continuous grinding experiments will be conducted in well-controlled laboratory mills.

A model for monosize particle-bed breakage based on single particle impact data has already been developed. It will be modified to include multisize particle beds and constraint. A model for the breakage and selection functions inside the ball mill will then be developed based on the modified particle bed breakage model and on the prediction of the impact energy spectrum within the mill from Discrete Element Simulation (DEM).

Progress

The microscale model for the disappearance rate of the parent size in a batch grinding experiment was further developed and validated against experimental data.

Low energy particle bed impacts are still being investigated to refine the particle bed breakage model. It has been shown that, although those very inefficient impacts individually produce little to no breakage in the impacted beds, they are responsible for inducing some mechanical damage in the particles. In smaller grinding mills these impacts are largely predominant and therefore accurate modeling is crucial for getting meaningful predictions out of the microscale model.

In parallel, the single particle properties measured on the Utah Ultrafast Load Cell are being compared to those from similar equipment installed in Australia. Equipment, software and operator influences on the measured fracture energies of three particular rock samples are being investigated.

1998 1st Semiannual Progress Report

Subaccount 49A5

Grant #G1155249

"Development of a Prototype Oscillating Ball Mill"

1995 - 1998

S. Jain - Graduate Student

R. P. King - Principal Investigator

Objective

The objective of this project is the development of a small prototype oscillating ball mill to demonstrate that comminution can be achieved in an energy-efficient manner using an oscillating bed of media rather than the conventional rotating bed. Two objectives have to be met in the design. An adequate rate of breakage and adequate throughput through the equipment to achieve production rates that ultimately would be of interest to industry.

Approach

The approach adopted is to understand the dynamics of oscillating media beds and the energy spectrum associated with particle-particle collisions in the medium bed. The dynamics of the media motion must be controlled to ensure both optimal impact energy spectra and optimal slurry motion through the bed.

Progress

We simulated a single ball oscillating mill to study the effect of change of amplitude on the chaotic motion of the bouncing ball. Initially the ball motion is simple harmonic, but on increasing the amplitude it bifurcates in period two orbit. Further, increasing the amplitude, we reach a critical table amplitude where the motion of the ball becomes completely chaotic.

It is seen that amplitude plays a very important role in the oscillating mill. Further simulations suggested that the critical amplitude (the amplitude above which the ball motion becomes chaotic) decreases with frequency. So for a high frequency, the critical amplitude will be low. Once we work with an amplitude above critical amplitude, the mill will have better porosity for those frequencies, resulting in efficient grinding. In a typical energy spectrum for a high frequency (> 4000 osc/min) and low amplitude (< 12 mm), most of the impacts are low-energy impacts.

Future work will concentrate on studying the effect of the number of ball layers and frequency on the energy spectrum and the porosity of the mill and come up with the specifications for the prototype oscillating mill.