Dynamic Simulation of Size Reduction Operations from Mine-to-Mill

by

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Outline

- Introduction
- A General Flowsheet Simulator
- Comminution Objects
- Simulation Case Study
- Future Capabilities
- Conclusions
The Hawaiian Islands

California

Mexico

Hilo

Hawaii

Tahiti

J.A. Herbst & Associates

Kona

Honolulu

Oahu

Molokai

Kauai

Australia
The Cost of Comminution Worldwide

Energy Consumed Worldwide
\[ \approx 2.6 \times 10^{10} \text{ US$/year} \]

Wear Parts Consumed Worldwide
\[ = 5 \text{ billion US$/year} \]
Typical Breakdown of Comminution Costs

- Explosive Fracturing: 1%
- Coarse Crushing: 2%
- Fine Crushing: 20%
- Grinding: 77%
Mine-to-Mill Simulation

Real World  Model Object  Flowsheet Simulator
Benefits of Object Oriented Programming

A software object contains code and data which simulate the pertinent characteristics of a physical device or stream.

Object Oriented

When process objects are connected by streams they are linked for computation.

Traditional

PROGRAM MAIN
CALL MINE ()
CALL TRUCK ()
CALL CRUSH(Feed, CrushProd)
CALL STORAGE ()
CALL SCREEN(Feed, ScreenProd)
CALL MILL(Feed, MillProd)
SUBROUTINE MINE ()
SUBROUTINE TRUCK ()
SUBROUTINE MILL(Feed, MillProd)
SUBROUTINE STORAGE ()
SUBROUTINE CRUSH(Feed, CrushProd)
SUBROUTINE SCREEN(Feed, ScreenProd)
Conceptual Design of MinOOCad
Implementation of MinOOcad
Models of Flowsheet Elements

Response

$\frac{t}{\tau}$ Longest Dwell Time
Dynamic/Multi-Components

Accumulation = Input - Output + Generation

\[
\frac{dM_{i,j}}{dt} = \dot{M}_{\text{In},i,j} - \dot{M}_{\text{Out},i,j} + f(M_{ij}'s)
\]

Particle Size Decreasing
Comminution Objects
- The Ball Mill

- Feature 1: Visualization
- Feature 2: Dynamic Performance Control
- Feature 3: Scale-up/Design
- Feature 4: Capital/Operating Cost

Knowledge Base  Manager  Computation Procedures
Input and Output User Interface

Ball Mill Object
Comminution Objects

- Mine
- Truck
- Storage
- Crushers
- Conveyors
- Screens
- Ball Mill - Pebble Mill
- SAG - AG Mills
- Sumps
- Hydrocyclones
Simulation Case Study

Mine → Primary Crusher → Coarse Ore Storage

Coarse Ore Storage → Secondary Mills

Secondary Mills → Primary Mills → SAG Mills

SAG Mills → Ball Mill
MinOOcad Flowsheet
Tool Bar and Property Page
Property Pages
Zoom on Property Page
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Base Case - At Steady State

Ball Mill
%L=70

SAG Mill
%L=12

Gyratory
%L=0

Mine
%L=0

Fraction Passing

Particle Size, microns

Predicted

Operating Data
Dynamic Situations Simulated

- Increase in Powder Factor at Mine
- Increase in Truck Haul Time
- Decrease in Stockpile Inventory
Increase in Powder Factor

Powder factor increased by 150%
Increase in Truck Haul Time

- Truck haul time increased by 25%
Decrease in Stockpile Inventory
Downstream Impacts

- SAG mill power
- Stockpile tonnage
- SAG mill tonnage
- SAG mill rock tons
- Begin stockpile inventory change

- Holdup, 1 or Ton/h, tph
- Power, kw
- % of Magnetite Liberated

- Begin change in stockpile inventory
- Ball mill P80, microns
- Ball mill magnetite liberated

- Time, hr
Future Possibilities

- Operating costs calculated on a minute-to-minute basis over the entire flowsheet
- Enterprise-wide control system capability integrated into simulator
- Incorporating the impact of maintenance using realistic wear and replacement models
- Embedding into control system software for on-line decision making
Conclusions

✦ Comminution comprises the most energy intensive and costly set of unit operations at a mine/mill site.
✦ Opportunities exist to improve "enterprise-wide financial performance" through understanding and exploiting dynamic/steady state interactions between comminution operations.
✦ A Windows based generic flowsheet simulator, MinOOcad, has been developed to allow dynamic simulation for any number of elements.
✦ Advanced comminution models embedded in well designed software objects can provide realistic simulations off all flowsheet elements.
✦ Potential uses for MinOOcad are broad and exciting.