Towards a Virtual Comminution Machine

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Introduction, Background and Objectives

Towards the end of the 1990's readily available personal computers became sufficiently powerful – when combined with an efficient numerical code – to use Discrete Element Modelling (DEM) in two dimensions for models involving a few hundred to a few thousand particles in commercially available packages. Some proprietary codes reported up to 200,000 particles (Herbst and Nordell, 2001 and Cleary, 2001)

In early 2000, JKMRC and CSIRO-MIS agreed to an informal collaboration with the objective of testing various DEM approaches against detailed process measurements. The initial collaboration demonstrated that 3D-DEM using spheres was sufficiently realistic for flow patterns and power estimation within tumbling mills. The results were reported in papers which were presented at SAG 2001 and in the technical literature. (Morrison et al, 2001; Cleary et al, 2003; Cleary et al, 2008)

The VCM will allow a comminution machine design which exists as a suitably detailed design in a 3D Computer aided design file (CAD) to simulate processing an ore (which has been characterised by suitable test work) to predict progeny, power consumption, wear and even machine component loadings.

Methodology

A "new" comminution device typically requires 15-25 years for development and to gain a sufficient degree of industrial acceptance to have any chance of commercial survival. Unsurprisingly, many promising devices suffer from interruptions to their development schedule or fail altogether for lack of development finance as much as any technical shortcomings.

There are also broader reasons for seeking more efficient ways to carry out comminution. It has been estimated that comminution processes world wide consume about 3% of all electricity generated (La Nauze et al, 2002). This compares with 1.3% by ore milling in North America (DOE report, 1981). Consumption of grinding media and wear resistant liners consumes about the same order of energy in terms of green house gas production (Musa and Morrison, 2007). Hence the total energy equivalent is more like 6%. In Australian terms, 10 and 20% are reasonable estimates. The current substantial pressure to reduce greenhouse gas production therefore provides a strong incentive to devise more energy efficient comminution devices, and to reduce the calendar time required for their development.

The most serious obstacle in the traditional approach to developing a new comminution device is the time and cost of building successive prototypes. Each prototype represents a substantial investment in development time and capital cost. Mechanical shortcomings such as component rigidity may cause rejection of a design with potentially good process performance. If at least some of the required prototypes can be constructed and assessed by simulation, then a large reduction in development time and cost should be possible. In many ways worse still are machines which work well at lab and pilot scale but cannot be scaled up to commercially viable sizes.

Each prototype cycle can easily cost 6-12 months of development time and tens to hundreds of thousands of development dollars. Hence, a system which can allow a good deal of the development work to reside in a simulation model has much to recommend it.

Experimental Technique

To be credible as a VCM, both the simulation program and the ore characterisation process must be thoroughly verified. Hence the VCM should also be useful for modelling and further development of existing comminution devices.

A VCM has the further advantage that variations on a theme can more easily be considered allowing estimation of the total energy "footprint" in terms of electrical energy and wear whilst treating "identical" simulated feed materials.

The Virtual Comminution Machine (VCM) must be able to relate each collision type and energy within a DEM simulation to the probable degree of breakage of that particle – based on characterisation tests of a particular ore. As several modes of comminution occur within tumbling mills, relating collision spectra to comminution represents a particular challenge.

The greater part of comminution energy is expended in a slurry environment in “wet” autogenous and semi-autogenous (AG and SAG) mills and ball mills. The proportion of fine (minus 37 micron) material in the slurry has a strong effect on its viscous properties. A reasonably viscous slurry which can retain particles on the surface of the grinding media helps to ensure selection of those particles for breakage. Hence the fluid and particle interactions are also important for particle breakage and transport. Models based on computational fluid dynamics (CFD) are not well suited to the high shear, high viscosity environment with complex free surface behaviour found in wet tumbling mills. DEM can be adapted to fluid modelling using Smoothed Particle Hydrodynamics (SPH), see Cleary (1998) and Cleary et al. (2007). The shear dependant viscosity model developed by Shi and Napier-Munn (2002) has been implemented in the CMIS code using SPH as a way to model mineral slurries.

In a DEM simulation, the forces exerted by each particle on the equipment surfaces are estimated. Therefore the relative wear rates can also be estimated using an appropriate wear model. Similarly, the total energy requirements for the machine can be estimated by summing the energies consumed by particle movement.

Conclusions and Future Direction

In short, the VCM objective is to model each process within any comminution machine to an acceptable level of accuracy so that it can be used as virtual development environment for existing and new comminution machines.

The VCM will always require powerful computational capabilities. A parallel devolvement is the UCM (Universal Comminution Model) which will embed VCM type relationships into a system suitable for desktop PCs (Powell et al, 2008)

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