CHAPTER 1 INTRODUCTION

Tumbling mills play an important role in the beneficiation of minerals. The main objective of grinding is to reduce the size of ore particles sufficiently in order to achieve liberation of a valuable mineral specimen. The process is energy intensive and costly, thus the proliferation of research aimed at cost reduction.

The reduction of energy costs can be achieved by focussing on either effective utilisation of the energy supplied by the comminution equipment or efficient liberation of the mineral grains. To achieve either of these two objectives a good understanding of the process involved is essential. Models have been useful in describing these complex processes.

The phenomenological model that uses the selection and breakage function parameters is now widely used in the design and optimisation of ball mill circuits. Extending the concept to Autogenous (AG) and Semi- Autogenous (SAG) milling has however been more difficult. The ball mill environment is mostly stable throughout the range of operating variables while AG/SAG mills can be subject to long or short term disturbances that can significantly alter the performance of the mill in a non-linear fashion. Estimating the correct parameters to match these changes is a big challenge for modellers.

The Breakage function is believed to be purely an ore dependent property and thus parameters can be established independent of any particular comminution equipment. Once these parameters have been established by some appropriate method (Austin and Luckie, 1971) for a particular material, they remain valid for any other comminution environment. It is generally assumed that this is true for (S)AG as well as ball and other mills.

The selection function on the other hand is very dependent on the milling environment. Methods for determining the selection function and possible correction factors for various milling conditions have been dealt with in the comminution modelling books by Austin et al (1984) and Napier Mann et al (1996). These factors cannot possibly represent all the possible configurations to be expected in the milling environment and new situations that fall beyond the established limits keep arising due to development of new equipment or even optimisation constraints.

The Discrete Element Method (DEM), a technique that can simulate movement of particles in any specified environment is not subject to such limitations. Thus it is a promising tool for predicting the selection function not only under familiar operating conditions but also for new situations. This requirement is essential for Semi and Autogeneous milling where the environment varies considerably.

The DEM can be easily incorporated into existing Population Balance Models (PBM) by using the energy output data to determine the selection function or can be combined with other models that may use the power, force or energy information from the DEM to calculate the breakage rate of target particles in a milling environment.

The main aim of this research was to develop a method that applies the energy spectra resulting from the DEM simulation, to predict breakage rate in any milling environment. This inevitably also required a clear determination of particle fracture response to energy input. Thus three main tasks had to be accomplished; development of the DEM code that provided the energy information in the required format and establishing a methodology for characterising particle fracture. The final task was to combine the DEM information with the particle fracture data to predict breakage rate of material.

1.1 Overview of the proposed Model

The model being developed will allow users to predict grinding rate of any mill provided the basic inputs about the material properties, mill geometry and operating conditions as shown in the Figure 1.1 are available. However, the mill load which is a vital input to the model has to be obtained by some other means.

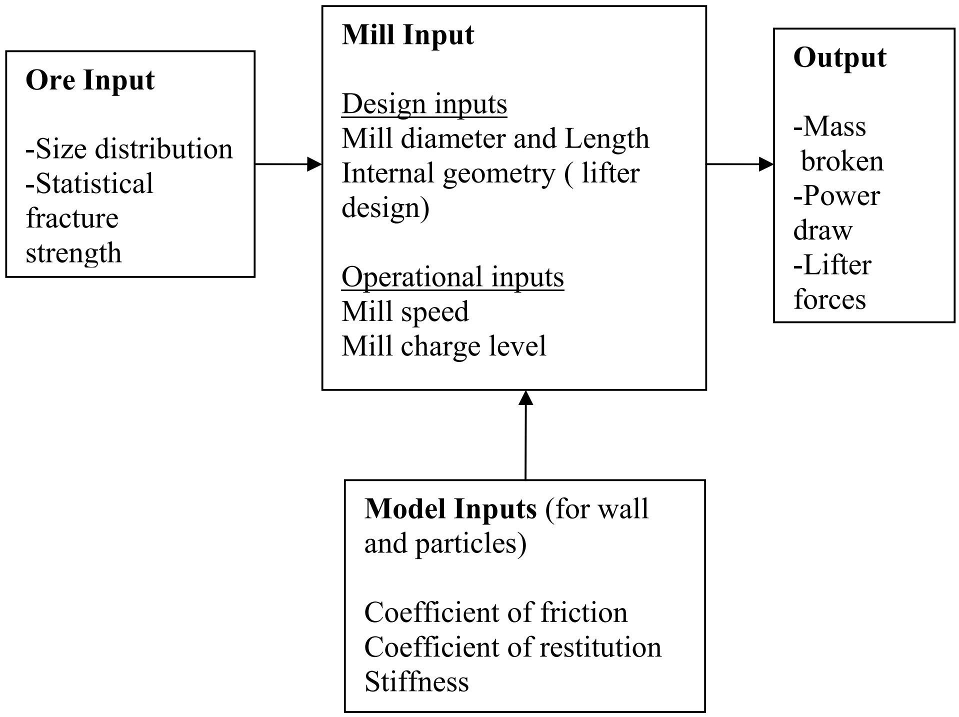

Figure 1-1 Elements on which the milling rate prediction model is based

1.2 Methodology

For the purpose of developing this model a scheme of experimental work was set up under well-defined conditions to provide data about the mill product under varying conditions. The simulations were also set-up under similar conditions and using the simulation output and other appropriate models, prediction of the experimental results was attempted. The approach is illustrated in Figure 1.2 below:

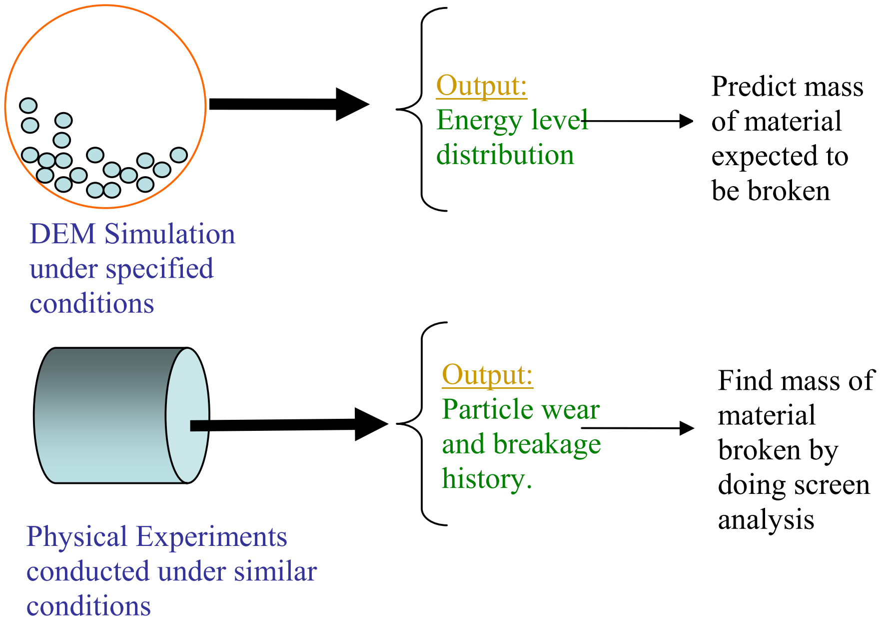

Figure 1-2 Parallel Simulation and Experimental Approach used to develop the breakage rate prediction Model

1.3 Scope of the work

Though the ultimate purpose was to establish a model that would predict SAG and AG milling under a wide range of conditions, it became evident during the research that the development of tools required was a formidable challenge and thus the focus was set simply to ensure that the necessary tools for predicting grinding rate were established. Thus instead of handling a full (S)AG mill size distribution, only two size fractions were evaluated, a media fraction which experienced little breakage and a target fraction which was fine enough to experience breakage. This approach did not only simplify the task at hand but also guaranteed more reliable data. It is shown in Chapter 7 that results of this approach are encouraging and thus a basis for extending this work to full (S)AG simulations has been established. It is in fact possible with the current status of the work to attempt (S)AG mill modelling by incorporating breakage rates of different particle sizes into existing Population Balance Models.

1.4 Structure of the thesis

The thesis is divided into two major sections; Chapters 3 – 5 cover the experimental work that involved material characterisation and grinding tests designed to generate data for evaluating the DEM based prediction models. Chapters 6 and 7 discuss the design of the simulation software and the development of the grinding rate prediction models. The thesis is concluded in Chapter 8. Below is a more specific review of each chapter.

Chapter 1: Introduction to the current comminution modelling approach and establishing why the DEM could offer a better solution.

Chapter 2: Review of various approaches to the application of Population Balance Modelling to predict milling operations. The essentials of the DEM scheme are discussed. The review also includes elements of fracture mechanics which are essential in the developing of the fracture model, a vital component of the breakage prediction scheme.

Chapter 3: Properties of the sample that would affect the determination of simulation parameters are examined, namely shape, density and size distribution.

Chapter 4: There was need to develop a material-dependent fracture model and the drop-weight tests that were designed to achieve this objective are discussed.

Chapter 5: Both abrasion and disintegrative fracture milling experiments conducted under various conditions for the purpose of comparing with the DEM simulation are discussed.

Chapter 6: Discussion of the design of the simulator, the role of parameters and the general simulation approach to the prediction of experiments is discussed.

Chapter 7: Development of the model that uses spectral energy data generated by the simulator and the fracture model developed from drop-weight tests to predict grinding rate followed by a discussion of the predictions.

Chapter 8: Summing up and giving recommendations.