

A New Macrophenomenological Concept of Comminution in Ball Mills

A P Yovanovic¹ and H P Moura²

ABSTRACT

Grinding is probably the single unit operation that requires the largest capital investment and operating costs in an ore beneficiation plant. Because of that, a great deal of research has been concentrated in the theory, design and operation of grinding equipment, in particular ball mills.

To-date, the models developed to describe grinding in tubular mills are macrophenomenological and can be divided into two categories: energetic and kinetic models.

This paper presents a new approach to modelling ball mill grinding: The Operational Model. The theoretical aspects of the model as well as a comparison with existing ones are discussed. The concepts of the model, summarised in easy-to-operate PC programs, permit the calculation and design of new ball mills, and a critical evaluation and optimising of mills in operation.

THE STATE OF THE ART

The general structure of modelling ore dressing processes considers, essentially, the description of the main process phenomena, the unit operations, and the auxiliary phenomena involved (classification, transport, etc in the specific case of grinding).

The main phenomenon can be described by the following approaches:

- Microphenomenological models that represent the process either chemically or physically;
- Statistical models that consider only the results of the process, and are based on a regression of a series of experiments instead of describing the process itself; and
- Macrophenomenological models that describe macroscopically a certain physical aspect of the process. For example: kinetic laws, separation curves, residence time distribution, among others.

To-date, the existing models of grinding in tubular mills are of the macrophenomenological type (Broussaud, 1988), and can be divided into two categories: energetic and kinetic models.

Both categories consider the evaluation of a certain macrophenomenological property measured either in laboratory or in pilot plant experiments. The design of the industrial mill is then carried out assuming the scaling up of this property, while the same approach should be followed when attempting to optimise industrial mills.

The grinding process involves three complex and simultaneous phenomena: comminution itself, which is the main phenomenon, (impact, attrition and abrasion), the auxiliary phenomena of classification of particles, and the macromolecular transport.

1. Civil-Chemical Engineer, Senior Mineral Processing Engineer, LEME Engenharia Ltd, Belo Horizonte, Brazil.
2. Mechanical Engineer, Senior Mineral Projects Consultant, LEME Engenharia Ltd, Belo Horizonte, Brazil.

Energetic approach

For a determined particle size range, the third theory of Bond (1961) establishes the relationship between the energy applied to the mill and the amount of energy the ore actually receives. For this same range, Bond presents a quantity known as the 'Work Index' (W_i , kWh/st). This constant, which can also be extrapolated to industrial mills, is an estimate of the net power consumption that shall be applied to the mill to reduce the actual ore sizing to an established size range.

This essential property, the 'Work Index', is obtained in laboratory mills working batchwise. This laboratory experiment was standardised by the simultaneous operation of an industrial mill used in the establishment of the Bond theory. Therefore, one may assume that in the design of a mill identical to the Bond reference mill (8.5 ft external diameter, 8.0 ft length, 70 per cent of critical speed, 37 per cent of ball load, pulp density of 77 per cent, etc) the laboratory experiments would lead to a very accurate prognostic of the ore behaviour in industrial scale.

Recent studies (Deister, 1987; Magdalinovic, 1989) have presented interesting suggestions to improve the reliability and scale-up of the parameters derived from Bond type experiments in laboratory.

Austin and coauthors (1982) point out four main disadvantages in the Bond method of calculation:

1. The specific power consumption differs from the calculated value if the reference conditions are changed: circulating load, ball charge, rheologic conditions, etc;
2. Bond clearly states that the specific grinding energy is not a function of the ball load, which has been proved inexact;
3. Bond's method uses only the F80 and P80 particle sizes, whereas mill capacity, in general, depends on the shape of the feed and product size distributions;
4. Under some conditions the Bond method does not clearly show the reasons for mill operational inefficiency.

All these shortcomings, except item 3, have been taken into account in the development of the Operational Model.

Kinetic approach

Batch experiments carried out in bench scale, within specific ranges of particle size, permit establishing the basic components of the kinetic approach (Broussaud, 1988):

B = Breakage function

where ' b_{ij} ' represents the mass fraction of the particles originally in size interval ' j ' and reduced to size interval ' i ' after breakage. It can be seen that ' b_{ij} ' is similar to a stoichiometric coefficient of a chemical reaction.

S = Selection function

