Effect of Medium Viscosity on Breakage Parameters of Quartz in a Laboratory Ball-Mill

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The role and effect of liquid medium viscosity on breakage parameters (S and B values) of the batch grinding kinetic model was investigated by grinding a single feed fraction of quartz (20 × 30 mesh) in a batch ball-mill at fixed mill loadings and at 45 vol % solid concentration, using glycerol–water mixtures of different proportions. The primary breakage distributions (B values) were normalized and separated into three different groups for grinding in media viscosities of 0.001(water), 0.002–0.03, and 0.08–0.16 Pa·s, respectively, with higher viscosity range giving proportionally finer products. The disappearance grinding kinetics of the top size showed that the specific breakage rates (S values) depended both on the viscosity of the liquid medium and on the extent of grinding. The specific breakage rates of the top size increased with the fineness of grinding while the breakage of the smaller sizes proceeded approximately in a first-order manner as characterized by a characteristic breakage rate constant. The acceleration of the top-size breakage rates as grinding proceeded was represented by a parameter called *the acceleration factor*, which correlated reasonably well with the changing slurry effective viscosity. Alternatively, the acceleration factor can be presented in the form of a single generalized first-order plot for grinding at different medium viscosities. The first-order breakage rate constant decreased with increasing medium viscosity over the range from 0.001 to 0.16 Pa·s but not linearly. The proportional variation of net mill power did not match exactly with that of the breakage rate constant on increasing medium viscosity. On the basis of the analysis of grinding results, three grinding regimes were identified relative to the change in medium viscosity but their existence was not confirmed experimentally.

Introduction

It is generally observed that ball-milling in water gives higher breakage rates than dry grinding both in batch and continuous operations.[1–5] This difference in grinding efficiency should be attributed to the difference in the mode of material movement in the mill charge, that is, powder flow versus slurry suspension flow, which in turn affects the way particles are captured and fractured by the grinding media. Most mineral slurries in grinding are non-Newtonian in character and their rheological properties are dependent on such parameters as particle size and shape, slurry concentration, temperature, and degree of particle dispersion. The easiest and most practical means of examining the rheological influence on particle breakage is by varying the percentage of solid-to-water ratio in the slurry, with grinding studies often being conducted in a small-scale batch mill. Batch tests in a laboratory mill can focus solely on the factors that affect breakage without the complicating effect of mass transport and the experiments are easier and quicker to perform and can be closely controlled. However, there is no guarantee that results from a small-scale mill will be similar to those in a larger mill.

Tangsathitkulchai and Austin[4] studied in detail the rheological influence on the specific rates of breakage (S values) and the primary breakage distributions (B values) of the batch grinding kinetic model by grinding a single feed fraction (20 × 30 mesh) of quartz and copper ore in water as a function of slurry density at a fixed mill speed and constant ball and powder loadings. The results indicated an increase in S values of the feed size as fines built up in the mill for slurry densities less than 60 vol % solid and deceleration of breakage rates at higher slurry densities. However, the breakage of smaller sizes was essentially first order once a naturally broken size distribution accumulated in the mill. The derived first-order breakage constant increased with increasing slurry density and went through a maximum at 45 vol % solid. The proportional variation of the rate constant with slurry density matched reasonably with that of the net mill power, signifying an approximate correlation between breakage and energy being expended in the mill. The B values were constant and normalized for normal slurry densities of <45 vol % solid but changed to a different set of values at higher slurry densities, with proportionally finer products.

Later, the effect of slurry density on the dynamics and grinding behavior of a laboratory batch ball-mill was reported by Tangsathitkulchai and Austin.[6] It was discovered that slurry density determined the spatial distribution of solid charge within the mill, with migration of particles from the tumbling zone to the mill wall as slurry concentration was progressively increased above 45 vol % solid. The overall effect gave rise to the change in the circulation path of the ball charge. In addition, the interaction between grinding media and the slurry under varying slurry density resulted in various grinding characteristics relevant to wet grinding systems. Recently, the work has been extended by Tangsathitkulchai[7,8] to identify and correlate the slurry

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