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A Study of Modeling between Surface Roughness and Work Index for Barite, Pyrite and Quartz

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ABSTRACT

Morphology properties, such as surface roughness, have a very important role in the minerals processing. Thus, understanding the relationship between surface roughness of the particles and their Bond work index is important. In this study, pyrite, barite and quartz with the work index of 4.73, 8.93 and 13.57 kwh/st are examined respectively. Results showed that with decreasing of particle size, particle roughness increased. Also surface roughness in the all size ranges is as following: barite> pyrite> quartz. Consequently surface roughness of the particles decreases with increasing of their bond index. Maximum particles roughness for barite, pyrite and quartz occurred in range of +177- 147 microns, that are equivalent to 41/193, 63/84 and 09/23 (dimensionless), respectively.

KEYWORDS

Surface Roughness, Work Index, Particles Size.

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1- INTRODUCTION

Surface roughness is considered as the most prominent feature of the surface. Since it is used in different fields, it is highly regarded by many researchers. This property of surface is due to fluctuations around solid surface (total surface topography), which obviously affects the reactivity of the solid [1]. Surface roughness clearly affects the reactivity of solids. The velocity of surface reactions increases with the increase of surface roughness, and it leads to the increase of high energy sites [2]. Surface roughness also affects the adsorption and interaction of particle - particle. In studies conducted by some researchers, it was reported that, crushing and milling operations bring about changes in physical and chemical properties of materials and affect the morphological properties, surface roughness of the particles, and subsequent mineral processing [3, 4]. Thus, the three-dimensional analysis is often used for measuring properties of particle morphology. The geometry of particles significantly affect the physical and chemical interaction of the surface. In this study, the importance of accurate assessment of the geometry of the particle is indicated by particle parameters. These parameters can be used to distinguish between materials and relate them with different processes [7]. The particles' roughness is calculated by measuring the BET gas adsorption. When the surface area is measured, the surface roughness can also be determined [8].

Surface properties, in particular, affect the processing operation of fine particles [2]. Therefore, the behavior and properties of particle depends largely on roughness, surface morphology and particle size of the particles. In mineral processing, operations such as flotation, jig, sieving, classification, shaking table, heavy media or dense media separation, cyclonic separation and etc. are dependent on the surface roughness and morphology of the particle [9, 10].

Bond specified work index parameter as the grind ability of the materials. The index equals to the work required to reduce a unit weight from a theoretical infinite size to 80% passing 100µm mesh. Bond index is considered as the inherent characteristics of each material and each material has a distinct band index [11]. The most important measurable physical properties of the particles is surface roughness which is a key parameters in predicting individual and collective behaviors of particles. These parameters for industrial applications of materials in powder form is of great importance; however, it has not been studied satisfactorily in the field of mineral processing. The aim of this study is to analyze roughness in different particles according to their work indices.

2- METHOLOGY

The required energy or work to reduce the particle with the size of y increases with the decrease of y. Many research works have been done to determine the function of work index. According to the survey of different factories, Bond understood that the required work for breaking a mineral is inversely proportional to the square root of y. Bond stated work index in terms of kwh / t and defined y as a size which 80 percent of the feed passes. K is constant and the work required to reduce the feed size (F) to the product size (P) equals to:

$$W = k(\frac{1}{\sqrt{P}} - \frac{1}{\sqrt{F}}) \tag{1}$$

Solving the equation 1 at limit condition of F= ∞ and P= 100 micrometers, Bond defined work index (W_i) as:

$$W_i = K\frac{1}{\sqrt{100}} \quad , \quad K = 10W_i \tag{2}$$

Therefore, using the equation 2 in the equation 1, the equation 3 is obtained:

$$W = 10W_i \ (\frac{1}{\sqrt{P}} - \frac{1}{\sqrt{F}}) \tag{3}$$

Advances in automated microscopy methods associated with computer systems (image analysis techniques) made it possible to determine the surface roughness by means of particles' cross-section using mathematic techniques. To determine the surface roughness simple methods such as determining the aspect ratio, the elongation ratio or roundness and new techniques such as Fourier analysis, delta analysis, and fractal geometry are used [7]. In this section the qualitative and quantitative concept of roughness is presented.

Since density or compression among different crystal planes varies, the surface may have various surface energies. Solid surfaces are prepared in different ways. Most of these methods cause the surface to become rough. In Figure 3 the real surface is XY and AB represents the hypothetical solid surface with an equivalent volume and a molecular flat surface. The equation (4) shows changes in the surface:

$$h_{av} = \frac{|h_1| + |h_2| + |h_3| + ... + |h_n|}{n} \tag{4}$$

Hilli Ilmaz suggest the surface area of the particles measured by BET and other methods of gas adsorption, surface roughness of the particles for measuring surface roughness of the particles. Assuming a regular geometric shape (spherical particles with D diameter) and using the equation 8, they recommend equation (9) to measure the surface roughness [5]:

$$r = \frac{A_{BET}}{6/(Dd)} = A_{BET}\, d(\frac{D}{6}) \tag{5}$$

A_{BET} = the measured BET surface area (gr/ m^2)

d = density of the solid (gr/m^3)

D = mean of the particle diameter (m)

r = surface roughness of the particle (dimensionless)

3- RESULTS

The minerals of Pyrite, Barite and Quartz in the range of - 1119+841 microns were first prepared and grinded by ball mill and the resultant product was classified in five sizes ranges from - 177+ 147, -147+104, -104 +74, +53-74 and -53 +44 microns. The results showed:

1 - The surface roughness grinded by the ball mill for all three types of mineral decreased with a decrease in size. It was expected that with a decrease in size the surface roughness increases but the surface roughness depends on both the size and the specific surface area. With a decrease of particle size, specific surface area increases, but the size of the particle decreases and the effect of decrease of size is more than the increase of the specific surface, so the surface roughness of the particle also decreased.

2 – In all size ranges, the surface roughness of Barite was more than Pyrite, and the surface roughness of Pyrite was more than Quartz which is probably due to the work index of the particles, i.e. Barite with the lowest work index enjoys the highest surface roughness and vice versa Quartz with the highest work index enjoys the lowest surface roughness.

3 - Linear Modeling of Barite, Pyrite and Quartz are the equations $S.R = 0.8098 * S + 62.15$, $S.R = 0.1894 * S + 55.74$ and $S.R = 0.1105 * S + 5.296$, respectively. Also, the correlation coefficient obtained from these models are 0.9836, 0.8414, 0.9843 (dimensionless), respectively, which indicates that the almost linear trend of surface roughness and the particle size.

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