Minerals Engineering 70 (2015) 1–7

Contents lists available at ScienceDirect

Minerals Engineering

journal homepage: www.elsevier.com/locate/mineng

Surface morphologies and floatability of sand-blasted quartz particles

O. Guven [a], O. Ozdemir [b], I.E. Karaagaclioglu [a], M.S. Çelik [a,*]

[a] Istanbul Technical University, Mining Faculty, Mineral Processing Engineering Department, Maslak, 34469 Istanbul, Turkey
[b] Istanbul University, Engineering Faculty, Mining Engineering Department, Avcilar, 34320 Istanbul, Turkey

ARTICLE INFO

Article history:
Received 22 April 2014
Accepted 1 August 2014
Available online 16 September 2014

Keywords:
Quartz
Roughness
BET
Flotation
Shape factor

ABSTRACT

Significance of morphological properties of minerals in flotation has been recognized for several decades but sufficient research efforts have not been devoted to this problem. In this study, a special design laboratory scale blasting equipment was used to produce quartz particles with different shapes and roughness values, and develop a new method by which flotation characteristics of quartz particles could be enhanced. For this purpose, micro-flotation experiments were carried out with un-blasted and blasted quartz particles, and the results were correlated with their shape and roughness values analyzed with SEM, BET, and Image analysis methods. The results indicated that the blasted quartz particles with more angular and rougher surfaces gave better floatability compared to the un-blasted quartz particles.

1. Introduction

Sand blasting treatment is an abrasive machining process which is widely used for surface strengthening (Guoying, 1998), modification (Jianxin and Taichiu, 2000), cleaning, and rust removal (Djurovic and Jean, 1999). In this treatment, sand particles are blasted with a shot gun through a nozzle under a certain pressure (bar) in order to change the surface characteristic of the particles.

The behavior of particle systems is primarily affected by the physical characteristics of particles such as size, shape, surface area, roughness, pore size, and structure (Chander and Hogg, 1988; Ulusoy, 1996). In order to describe their physical characteristics, simple linear parameters such as the length, breadth, width, and the ratios of these dimensions can be measured, and used as coefficients to characterize the shape factors in terms of such properties as the aspect ratio, elongation ratio, roundness etc. (Sarkar and Chaudhuri, 1994; Meloy and Williams, 1994; Singh and Ramakrishnan, 1996).

Roughness is another important parameter which is most likely formed due to the fluctuations around a smooth and sharp interface (Szleifer et al., 1986). Almost all surfaces in nature appear smooth for naked eye but they are microscopically rough in various ranges at micro or nano scale. Since the method selected for roughness measurement is important for obtaining reliable data, the morphological characterization of powder sized materials is conducted by two dimensional microscopic measurements from polished sections. However, the main disadvantage of these methods is that the polished sections alter the real morphology of particles (Medalia, 1980). Therefore, three dimensional analyses like BET adsorption by N_2 have often been used to obtain reliable data on particle surfaces (Brunauer et al., 1938). Once the surface area is measured, the roughness of surface can be characterized (Lange et al., 1993).

Flotation is a well-known physico-chemical process exploiting differences in surface properties of minerals which depend on wettability or hydrophobicity of particles. Additionally, there are several parameters acting on the efficiency of flotation processes besides other parameters such as collector type, pH, particle size, shape, and other morphological properties of particles. There are several studies on flotation behavior of a liquid partially wetting smooth and rough surfaces (Ulusoy and Yekeler, 2005; Yekeler et al., 2004; Rezai et al., 2010). However, in a real world, no surface is totally smooth; hence the status of rough surfaces is still not clear. Moreover, the particle surface roughness with sharp protrusions and edges have a significant effect on film thinning and rupture, which in turn influences the fundamental processes of particle–bubble attachment and other sub processes in flotation (Koh et al., 2009).

In this study, sand blasting equipment was developed and used as a novel approach for producing rough quartz particles at different nozzle pressures. Then, the flotation experiments were carried out with un-blasted and blasted quartz particles in order to investigate the effect of morphology of quartz particles on their flotation behavior.

* Corresponding author.
E-mail address: mcelik@itu.edu.tr (M.S. Çelik).

http://dx.doi.org/10.1016/j.mineng.2014.08.007
0892-6875/

2. Materials and methods

2.1. Materials

The quartz sample used in this study was provided by ESAN mining company, Istanbul, Turkey. The chemical and mineralogical analyses of the sample were carried out by X-ray Fluorescence (XRF) and X-ray Diffraction (XRD) methods, respectively. The results presented in Fig. 1 and Table 1, clearly indicate that the sample was pure enough to carry out the experiments.

Table 1
Chemical analysis of the sample.

Compound	% by weight
SiO_2	98.970
Al_2O_3	0.632
Fe_2O_3	0.095
TiO_2	0.095
MgO	0.096
CaO	0.035
Na_2O	0.034
K_2O	0.043

2.2. Methods

2.2.1. Grinding

The quartz sample was first comminuted by a series of crushers involving jaw, cone, and roll crushers to obtain the particles less than 2 mm in size for the sand blasting experiments. The sample was then ground in a ceramic cylindrical mill. After the grinding, the sample was dry screened using a Ro-Tap sieve shaker for 30 min to obtain samples of an exact particle size of −0.150 + 0.075 mm, and this sample was analyzed in terms of shape factor and roughness, and micro-flotation studies.

2.2.2. Sand blasting

A series of tests were adopted with the uniquely designed sand blasting machine (Fig. 2) to investigate the effect of blasting on the morphological properties of quartz particles, hence their flotation recoveries. For this purpose, 100 g of crushed quartz sample of less than 2 mm in size was fed to the blasting machine. The quartz particles were blasted with an air stream fan across a high Mn-stainless steel plate where the diameter of nozzle (d) used was 2 cm. The feed speed was kept constant as 0.94 g/s. The air pressure ranged from 1 to 6 bar, and the distance (L) between the plate and nozzle was taken constant as 14 cm.

In this study, a numerical calculation method based on the relation between air pressure (p) and particle velocity (V_p) was used as described in Eq. (1).

$$V_p \alpha p^{n_v} \tag{1}$$

Based on the literature data, the power exponent n_v was taken as 0.60 (Fokke, 1999) for calculating the particle velocity and plotted against air pressure in Fig. 3.

After the sand blasting, the same screening procedure was applied on the blasted sample to obtain 150 × 75 μm sized samples. And these samples were also taken for the analysis of the shape factor and roughness, and the micro-flotation studies. The tests were repeated three times in order to obtain reproducible data for evaluating the effect of sand blasting on particle morphology. It is important to note that the same size fraction of 150 × 75 μm was always used in the flotation experiments. Therefore, the particle size was always kept constant after grinding and blasting processes in order to understand the effect of particle morphology on floatability of quartz.

2.2.3. Sample characterization

The ground (un-blasted) and blasted samples of 150 × 75 μm in size were analyzed using QUANTA FEG250 Scanning Electron Microscope (SEM) at magnifications higher than 1500× in order to detect the morphological changes on the particles surfaces.

The image analysis for each representative sample was also performed with Leica QWin Image Analyze Program (Leica QW in User Manual, 1995) based on the particle projections obtained from the photographs. The roundness (Ro), flatness (F), elongation ratio (ER), and relative width (RW) of about 150 particles were automatically calculated by the image analysis software defined as follows (Forssberg and Zhai, 1985):

$$\text{Roundness (Ro)} = \frac{4\pi A}{P^2} \tag{2}$$

$$\text{Flatness (F)} = \frac{P^2}{4\pi A} \tag{3}$$

$$\text{Elongation Ratio (ER)} = \frac{L}{W} \tag{4}$$

$$\text{Relative Width (RW)} = \frac{W}{L} \tag{5}$$

Additionally, the surface roughness evaluation based on the specific surface area (area per unit mass or volume) of the un-blasted and

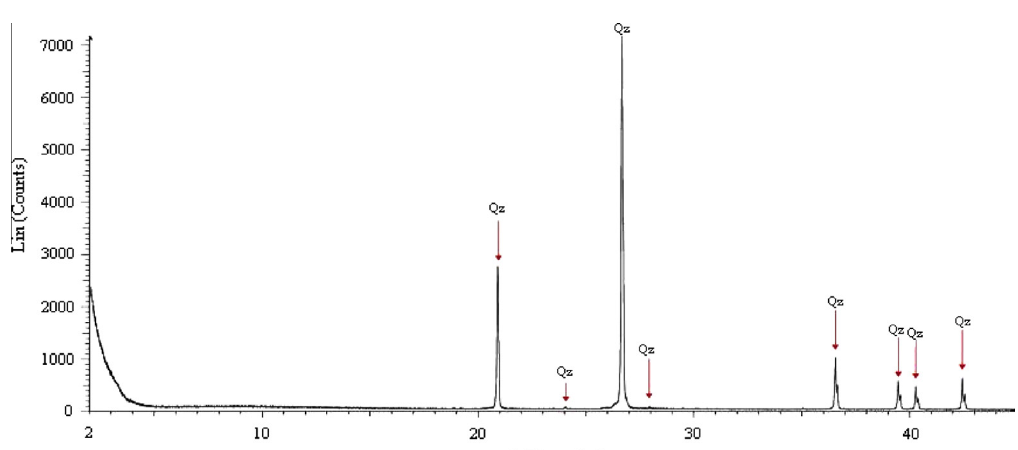

Fig. 1. XRD analysis of quartz sample.