Fizykochemiczne Problemy Mineralurgii, 29 (1995), 31–38

Cahit HIÇYILMAZ*, Sedat BILGEN*, Ümit ATALAY*, Uğur ULUSOY**

EFFECT OF SHAPE CHARACTERISTICS OF PARTICLES ON FLOTATION

Shape and morphological properties of barite and pyrite particles ground by autogeneous and ball milling have been examined by using Scanning Electron Microscope (SEM). Hallimond tube flotation tests were performed to evaluate the floatability of particles ground in different environments. Measurements and SEM observations revealed that particles with lower flatness and higher degree of roundness have better floatability.

1. INTRODUCTION

In mineral processing grinding is essential to liberate valuable minerals from gangue. It has been reported that shape properties of ground particles affected flotation.

Fahlström (1974) observed that autogeneous grinding products had lower compactness than conventional milling, which resulted in more selective flotation and better concentrate grades. Forssberg and Zhai (1985) found that autogeneous grinding generated rounded particles with higher degree of liberation and consequently higher grade concentrate and better recovery.

On the contrary, low floatability of prereduced ore particles was presumed to be caused by rounded shape of particles (Hoberg and Scheneider 1978). Huh and Mason (1974) stated that particle shape and adhesion force between bubble and particle are strongly related. Detachment of rounded particles from a bubble was demonstrated to be more likely to happen than the detachment of prismatic particles (Wotruba et al. 1991).

In spite of contradiction it is obvious that shape characteristics of particles are effective in flotation.

This paper presents the results of a study on the effect of particle shape on flotation. Comparison of the grinding systems is not the scope of this study; autogeneous and ball milling have been applied just to have particles with different characteristics.

* Mining Engineering Department of Middle East Technical University, Ankara, Turkey.
** Mining Engineering, Department of Cumhuriyet University, Sivas, Turkey.

2. MATERIALS AND METHOD

Materials

In this study, high grade barite and pyrite samples from Beyşehir and Küre Mines of Etibank Turkey, respectively, were used. The analyses showed that the barite sample contained 94.22% $BaSO_4$ whereas the pyrite sample contained 96.89% FeS_2, indicating that both the samples were pure enough for this research.

Sample Preparation and Equipment

For dry autogeneous grinding a 430x225 mm laboratory scale autogeneous mill with rubber lining was used. Conventional grinding tests were carried out in a laboratory scale porcelain ball mill with a dimension of 150x205 mm. The charge for autogeneous grinding tests was consisted of three fractions, namely 3.0 kg of −80+50 mm, 2.0 kg of −10+1 mm and 1.0 kg of −1+0.147 mm, totaling 6.0 kg.

During dry ball milling, the grinding medium used in the porcelain mill was 3.0 kg of stainles steel balls of the sizes 25 and 19 mm. Feed size of the ore was 1.3 kg of −10+1 mm and 0.7 kg of −1+0.147 mm.

6 minutes of ball milling gave similar size distribution with 4 minutes of autogeneous grinding for barite sample and 23 minutes of ball milling gave similar size distribution with 20 minutes of autogeneous grinding for pyrite sample, providing a comparative study on the shape characteristics.

A Jeol-840 Scanning electron microscope was utilized to picture the representative samples from the sieved fractions for the axes measurements. The particles with no overlapping and no border out of the picture frame were chosen for the measurements. About 300 particles were examined for each fraction where 5 linear lengths and 5 linear widths were measured from each particle. The average of these lengths and widths were taken as length (L) and width (W) for that fraction.

Flotation tests were performed in multi-bubble Hallimond tube with nitrogen bubbling. For barite flotation A 845 (Cyanamid) succinamate surfactant was used as a collector with a dose of 66 g/ton. The pH level was adjusted to 10.5 by NaOH and barite was floated for 5 minutes. For pyrite flotation, on the other hand, 10 g/ton Na_2S for cleaning of surface oxidation products and 50 g/ton Na ethyl xanthate as collector were used. Conditioning times were 5 minutes for each reagent and the froth was collected for one minute.

3. SHAPE CHARACTERISTICS

For characterization of the shape of a particle, a simplified method (Forssberg and Zhai 1985; Hagerman et al. 1980) has been used. The method calculates the area (A) and perimeter (P) of a particle assuming that the projection of the particle has an ellipse – like shape with the axes of length (L) and width (W).

According to Beyer (1978) A and P can be written as

$$A = \frac{\pi}{4} LW \tag{1}$$

$$P = \frac{\pi}{2}\left(\frac{3}{2}(L+W) - \sqrt{LW}\right) \tag{2}$$

The shape characteristics studied are flatness, roundness, degree of axial equality, relative width and elongation ratio. The following two parameters can be defined relative to circle:

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

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

As seen from the Eqs. 3 and 4 flatness is actually inverse of roundness. Roundness has its maximum at 1.0 for a circle. Conversely, flatness has its minimum value of 1.0 for a circle.The other shape parameters can be written as:

$$\text{Elongation ratio} = \frac{L}{W} \tag{5}$$

$$\text{Degree of axial equality} = \frac{A}{L^2}\cdot\frac{4}{\pi} \tag{6}$$

Substituting the Eq. 1 into the Eq. 6 reduces the equation to W/L which is defined as relative width.

Degree of axial equality and relative width increase with decreasing major axis length of the projected particle and hence more rounded grains can be observed.

Elongation ratio and flatness increase with increasing major axis length of the particle, resulting in more elongated particles.

4. RESULTS AND DISCUSSION

Barite Sample

The results of measurements of axes revealed that the particles ground by autogeneous mill have lower flatness and elongation ratio together with higher degree of axial equality and roundness compared to the ball mill products (Table 1). To make comparison more clear the relative flatness was also included in Table 1. Relative flatness is the ratio of the flatness of ball mill to that of autogeneous mill. The values of relative flatness are above 1.0 in every size fraction, implying that unevenness of ground particles increases when ball milling is applied.

The flotation results of barite are shown in Figure 1. Test results indicated that floatability increases in case of autogeneous milling. Autogeneous grinding which generated particles with lower flatness, elongation ratio and perimeter length gave better flotation recoveries than those of ball mill grinding. As seen from Figure 1 that as roundness of the projected particles increases, flotation recoveries increase, pointing out the positive effect of roundness on flotability.

Pyrite Sample

The results of measurements of axes given in Table 2 showed that the particles ground by ball mill have lower flatness and elongation ratio with higher degree of axial equality and roundness than the autogeneous mill products. The values of relative flatness are belove 1.0 in every size fraction, showing that unevenness of ground particles increases when autogeneous grinding is applied.

Figure 2 shows the flotation test results. The problem for the pyrite flotation was the oxidation of mineral surfaces. Since the oxidation was inevitable, it was attempted to obtain an equal degree of oxydation by doing the experiments within similar time durations.

The flotation test results show that the flotation recovery of the particles ground in ball mill is higher at each fraction. In other words, the particles which are rounder in shape showed better flotation response. The elongation ratios in Table 2 also support these results. The particles ground in autogeneous mill have higher elongation ratios, that is, the floatability of the elongated particles is not as good as the floatability of the round ones.

These results seem to be in very good agreement with those of the investigations by Fahlström (1974) and Forssberg and Zhai (1985). They also found that the selective flotation of the particles with higher roundness resulted in higher concentrate grade.

The barite particles ground in autogeneous mill and the pyrite particles ground in ball mill were more rounded in shape. This seems to be contradictory but, actually, it is not.

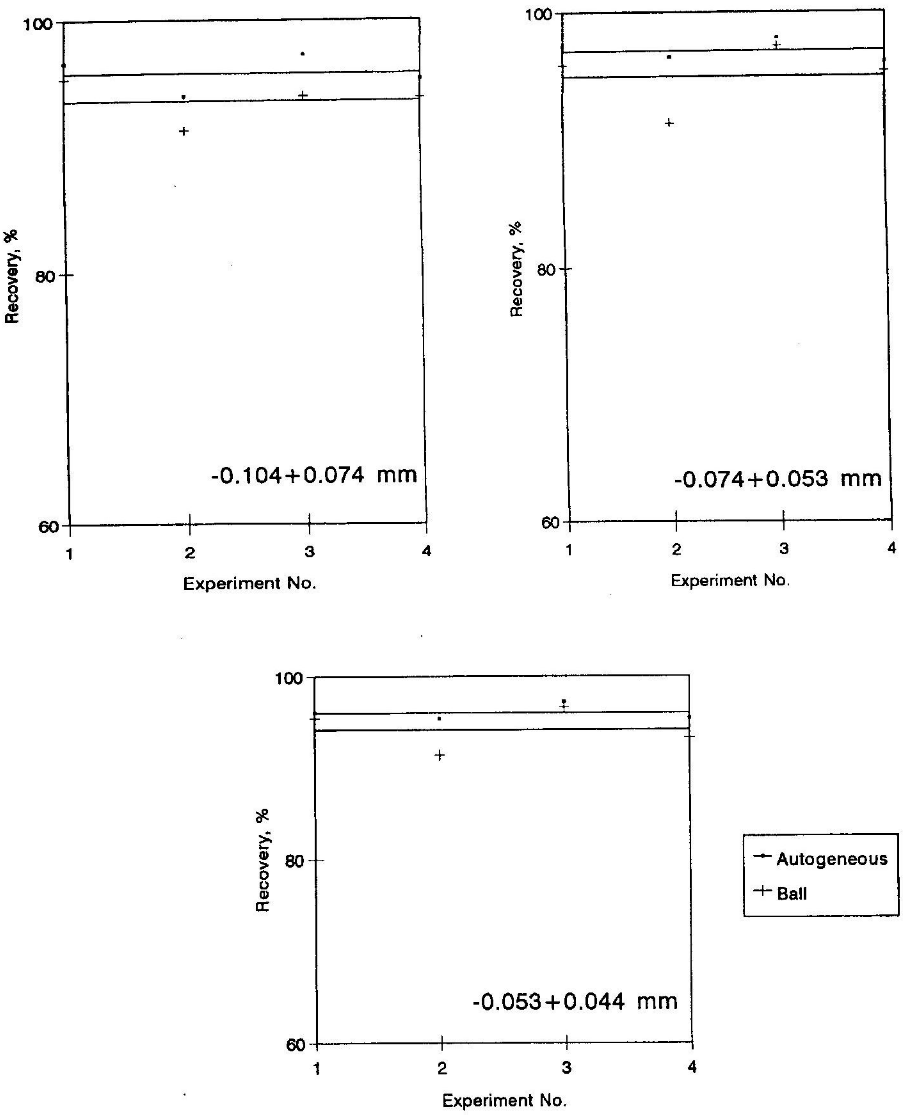

Fig. 1. Flotation results of barite sample

The comparison of autogeneous and ball mills from the flotation point of view is not the scope of this study. These grinding methods were applied just to produce the particles differing in shape. The comparison of the grinding systems with the presented data would lead to wrong conclusions mainly because the simulation of autogeneous grinding is not as easy as the simulation of conventional grinding and requires much more extensive grinding tests. Moreover, the speed of ball mill, which runs at constant speed by design, was 58.5% critical speed, being lower than

Table 1. The shape characteristics of barite particles calculated from SEM study

Particle size μm	Grinding type	*L* μm	*W* μm	*P* μm	*A* μm^2	Roundness	Flatness	Degree of axial equality	Elongation ratio	Relative Flatness
-0.104 +0.074	Ball	117.295	84.320	318.828	7767.834	0.9603	1.04135	0.565	1.391	1.00468
	Autogenous	100.407	73.626	274.998	5806.107	0.9648	1.0365	0.576	1.364	
-0.074 +0.053	Ball	71.262	52.077	194.919	2914.70	0.9640	1.0373	0.574	1.367	1.0025
	Autogenous	67.549	49.892	185.524	2646.913	0.9664	1.0347	0.580	1.353	
-0.053 +0.044	Ball	58.125	39.423	154.649	2799.710	0.9456	1.0575	0.533	1.475	1.02789
	Autogenous	50.344	37.793	139.151	1494.338	0.9720	1.0288	0.589	1.332	

Table 2. The Shape Characteristics of Pyrite Particles Calculated from SEM Study

Particle size μm	Grinding type	*L* μm	*W* μm	*P* μm	*A* μm^2	Roundness	Flatness	Degree of axial equality	Elongation ratio	Relative flatness
-0.104 +0.074	Ball	101.127	73.615	276.193	5846.731	0.963	1.038	0.728	1.374	0.994
	Autogenous	96.793	68.761	261.932	5227.413	0.958	1.044	0.710	1.408	
-0.074 +0.053	Ball	81.371	58.084	220.595	3712.115	0.959	1.043	0.714	1.401	0.999
	Autogenous	66.957	47.650	181.312	2505.851	0.958	1.044	0.712	1.405	
-0.053 +0.044	Ball	63.060	45.334	171.411	2245.266	0.961	1.041	0.719	1.391	0.975
	Autogenous	55.887	36.713	147.035	1611.537	0.936	1.068	0.657	1.522	

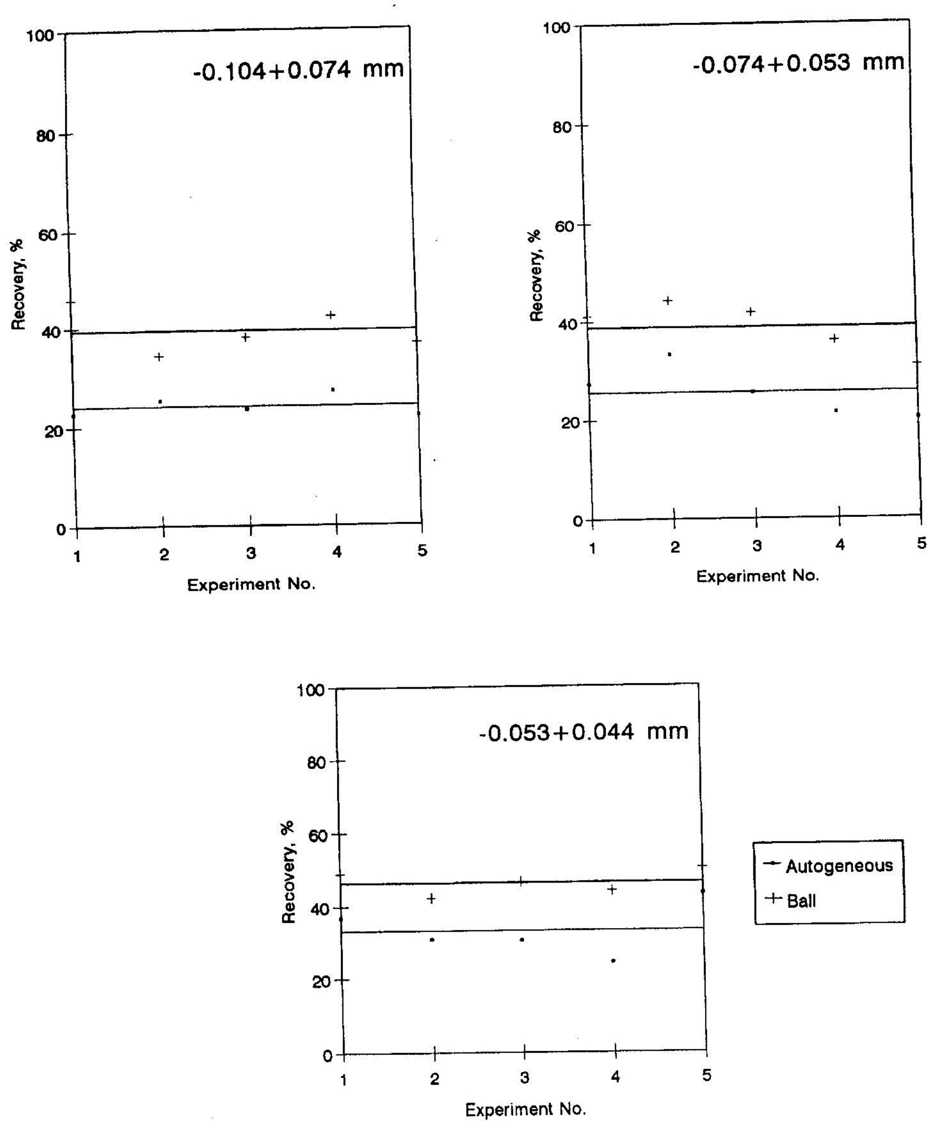

Fig. 2. Flotation results of pyrite sample

it should be. Actually, higher mill speed could make the difference in shape characteristics more distinctive.

Therefore this study refers the flotation behaviour of the particles to the shape properties not to the grinding systems.

5. CONCLUSION

Although the mechanism how the shape of a particle affects the flotation is to be determined it has been found that the particles having higher roundness and degree of axial equality, lower elongation ratio, and flatness showed better floatability.

REFERENCES

BEYER W.H. (1978), *Handbook of Mathematical Sciences*, CRC Press, Florida.
FAHLSTRÖM P.H. (1974), *CIM Bulletin*, 78, 127.
FORSSBERG E. and ZHAI H. (1985), *Scandinavian J. Metallurgy*, 14, 25.
HAGERMAN T.H., BLACK K. and LILLIESKÖLD (1980), *Swedish Council for Building Research*, D26.
HOBERG H. and SCHNEIDER F.U. (1978), *Freih Fersch. H.A.*, 593, 149.
HUH C. AND MASON S.G. (1974), *J. Colloids and Interface Sci.*, 47, 271.
WOTRUBA H., HOBERG H. and SCHNEIDER F.U. (1991), *Preprints, XVII Int. Min. Process. Cong.*, Dresden, Germany, Vol. IV., 83.

Hiçyilmaz C., Bilgen S, Atalay Ü., Ulusoy U., (1995), Wpływ kształtu ziarn na ich flotowalność, *Fizykochemiczne Problemy Mineralurgii*, 29, 31–38 (English text)

Skaningowym mikroskopem elektronowym badano kształt i morfologiczne właściwości ziarn barytu oraz pirytu rozdrabnianych w młynie samomielącym i w młynie kulowym. Przeprowadzono również testy flotacyjne w celce Hallimonda, aby ocenić flotowalność ziarn rozdrabnianych w różnych warunkach. Badania flotacyjne i obserwacje mikroskopowe wykazały, że ziarna płaskie z wysokim stopniem okrągłości flotowały lepiej niż inne ziarna.