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Dry Grinding Kinetics of Gölbaşı (Ankara) Andesite in Ball Mill.

T. Agacayak and A. Aras*

Selcuk University, Mining Engineering Department, Konya, Turkey

*Email: aliaras@selcuk.edu.tr

Abstract: Kinetic study using a laboratory steel ball mill was carried out to determine dry grinding properties of andesite sample. The S_i (specific rate of breakage) values were determined by using the single sized feed fractions of -850+600 µm, -600+425 µm and -425+300 µm. Dry grinding of single size intervals showed that andesite followed the first-order breakage law. The breakage parameters of andesite in terms of the S_i, a_T and α values were determined.

Introductıon

Andesite is a fine-grained volcanic rock that has a silica content of 53–63%. It has a porphyritic texture and is composed of plagioclase and pyroxene microliths (clinopyroxene and orthopyroxene), feldspar, pyroxene and biotite phenocrysts in a glass matrix and magnetite minerals in small amounts. Depending on its dark colour mineral components, the colour of andesite varies from light grey to grey, dark grey, black and reddish–brownish–pinky tones (Koca et al., 2001, Sariisik et al., 2011, Aydar et al., 2003).

Andesite is used in civil engineering and architectural procedures such as production of pavements, kerb-stones, staves, coping, windowsills, jambs, and friezes (Sariisik et al., 2011).

Andesite is also used in blended cement production as pozzolanic material. During cement production, use of additive materials that have pozzolanic property could affect the quality of concrete favorable (Terzibasıoglu, 1995). Pozzolanic materials (siliceous or siliceous–aluminous material) which in itself have no binding property, but in ground form and the presence of moisture, chemically react with calcium hydroxide to form compounds possessing hydraulic binding properties (Terzibasioglu, 1995, Alp et al., 2004).

In this study, grinding properties of andesite sample that is one of the natural pozzolanic materials was studied.

Theory

A lot of studies related to breakage of the materials show that the rate of breakage of particles follows first-order breakage kinetics.

Hence, the rate of breakage of size is given in Eq. (1) (Austin and Luckie, 1972; Klimpel, 1997):

$$S_i w_i(t) W \qquad (1)$$

Where w_i is the weight fraction of material of size i, W is the total powder mass in the mill. S_i is the specific rate of breakage of size i. Thus, Eq. (1) becomes as follows:

$$d[w_i(t)W]/dt = -S_i w_i(t) W \qquad (2)$$

Total mass, W, is constant and if S_i doesn't differ with time, then Eq. (2) will become as:

$$w_i(t)=w_i(0)\exp(-S_i t) \qquad (3)$$

In Eq. (3), $w_i(t)$ and $w_i(0)$ are the weight fraction of size i at time t and zero, respectively (Austin et al. 1984).

Materıals and Methods

Andesite sample used in grinding experiments was obtained from Gölbaşı district of Ankara. The sample was crushed and prepared to –850+600 µm, –600+425 µm, and –425+300 µm feed size fractions for the grinding experiments

A steel laboratory ball mill was used in grinding experiments. The properties of the ball mill used and grinding conditions are given in Table 1. The experiments were carried out using single sized feed fractions (Austin et al., 1984) and these fractions were batch ground for different time. A sample of approximately 45 grams was taken from the ground material for screen analysis and breakage parameters of andesite sample were determined.

Table 1. Ball mill properties and grinding conditions.

Mill	Inner diameter, mm	200
	Length, mm	191
	Volume, cm^3	6000
	Critical speed, rpm	101.1
	Operational speed, rpm	76
Media (Balls)	Material	alloy steel
	Diameter, mm	25
	Number	92
	Specific gravity, g/cm^3	7.8
	Fractional ball filling	0.2
	Powder-ball loading ratio	0.5
	Fractional powder filling	0.04

Results and Discussion

Determination of Specific Rates of Breakage

The S_i (specific rate of breakage) values of andesite sample in 850+600 µm, -600+425 µm and -425+300 µm fraction ground in steel ball mill for different time were given in Figures 1-3.

As seen from Figures 1-3, dry grinding of andesite sample presents the first-order breakage form. However, it was determined that as the feed size became coarser, S_i values increased. That is, while the highest S_i value obtained was 0.216 min^{-1} for -850+600 µm and the lowest S_i value was 0.196 min^{-1} for -425+300 µm feed. In Figure 4, variation of the specific rates of breakage (S_i) against feed sizes which is obtained from first-order plots in Figure 1-3 was shown. The values of S_i can be fitted to the Eq. (4):

$$S_i = a_T(x_i / x_0)^{\alpha} \quad (4)$$

In Eq. (4), x_i is the upper limit of the size i, x_0 = 1000 µm, a_T and α are model parameters depend on grinding conditions and properties of material.

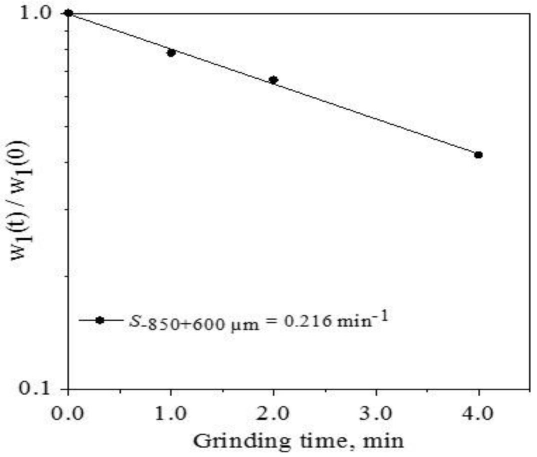

Fig. 1 First-order plot for –850+600 µm feed size of andesite sample.

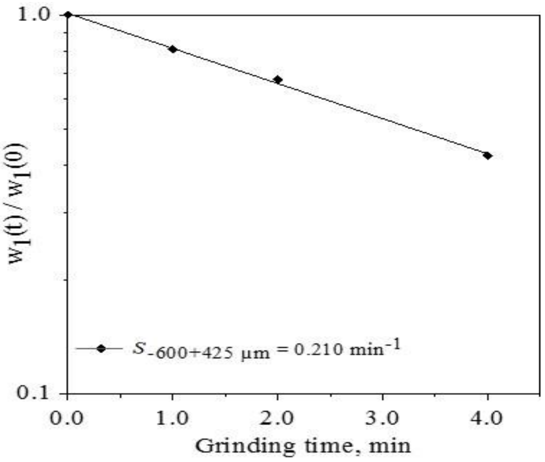

Fig. 2 First-order plot for –600+425 µm feed size of andesite sample.

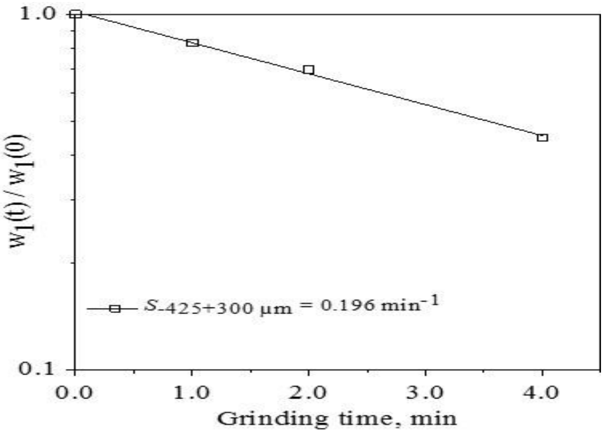

Fig. 3 First-order plot for –425+300 µm feed size of andesite sample.

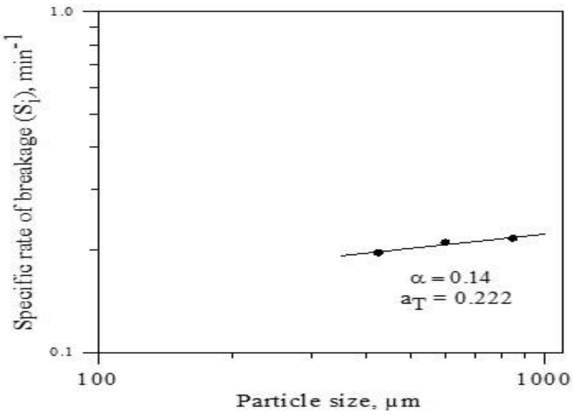

Fig. 4 Relation of $S_i$values of andesite sample with particle size.

Using the experimental results obtained from this study, breakage parameters of andesite sample were compared to other materials (barite, calcite, colemanite, zeolite) under the similar experimental conditions. It was found that andesite sample was broken slower than these materials in terms of S_i, a_T and α value (Aras et al., 2008, Teke et al., 2002, Bozkurt and Ozgur, 2007, Ozkan et al., 2009). It could be considered that, this case occured due to high silicate content and heterogeneous structure of rock (Bozkurt and Ozgur, 2007; Ipek et al., 2005).

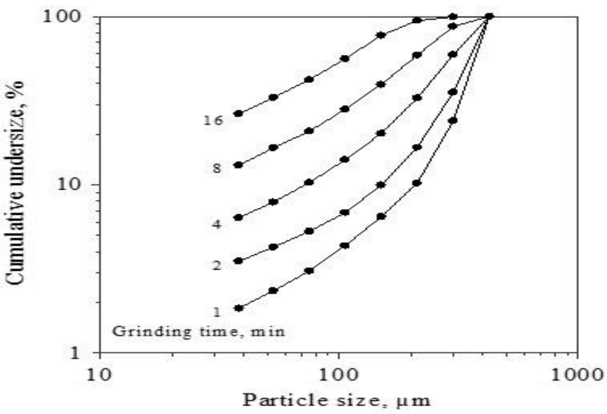

Fig. 5 Product size distribution from dry grinding of -425+ 300 µm andesite sample.

Determination of Particle Size Distribution

Particle size distribution of dry grinding of andesite sample at various times for -425+300 µm feed size fraction was given in Figure 5. As seen, approximately 80% passing size of the material ground in the mill reached 150 µm at a grinding time of 16 min.

Conclusion

Dry grinding of single size intervals of andesite sample showed that this material suited to the first-order breakage law. When the top sizes fed to the steel ball mill increase, the specific rate of breakage (S_i) values increase as well, showing a more rapid breakage of the top sizes.

The characteristic breakage parameters of andesite sample obtained from experiments were a_T= 0.222 min^{-1} and α= 0.14.

Breakage parameters of andesite sample were compared to other materials (barite, calcite, colemanite, zeolite) under the similar experimental conditions. It was specified that andesite sample was broken slower than these materials.

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