Prosimy cytować jako: Inż. Ap. Chem. 2009, 48, 4, 34-37

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The effect of feed particle size on breakage rate parameter in a pilot scale ball mill

Introduction

Many exhaustive industrial studies established that grinding is highly energy intensive unit operation in mineral processing and cement production. Conventional cement making process approximately consumes 110 kWh electrical energy to produce one ton of cement and one-third of this energy, which usually lies between 32–37 kWh/t for cement with a Blaine of 3500 cm^2/g [1], is expended in the clinker grinding step. Whole cement production of the world is about 2.6 billion tons [2] and 172000 GWh electrical energy has been consumed for grinding process. This shows that such large amounts of energy and environmental concerns justify the need to improve the energy efficiency of grinding process.

In the conventional cement production, grinding of clinker is carried out in multi-compartment ball mill operating with an air separator in closed circuit. Significant advances have been made in the explaining of relationship between operating variables of ball mill and grinding kinetic to achieve optimum performance. However, it is still necessary to have better knowledge about the effects of mill operating variables such as feed particle size, ball size, ball media distribution.

Particle size is one of the significant parameters influencing the grinding kinetic and in selecting of optimum ball size in ball mills. That is why it forces researchers to describe the more accurate relationship between particle size-grinding kinetic and particle size-optimum ball size. However, no completely definitive test study on particle sizes to quantify these relationships was found [3]. On the other hand, most of the data published in the literature are based on small diameter ball mills. They do not show significant effect of ball size on their grinding performance. This causes not to describe the effects of particle size and other parameters on grinding kinetics. Such studies developed using laboratory ball mill data are not directly applicable to industrial systems without scale-up as in the work of *Austin* et al. [4]. To overcome this deficiency, a research program was in progress to investigate the effect of operating parameters on grinding kinetics using data collected from operating plants and pilot scale ball mill. *Erdem* et al. [5] study is addressed to see the effects of ball size on grinding kinetics.

This paper deals with the experimental studies on two different size feed samples and investigation of the influences of feed size on breakage rate in pilot scale ball mill.

Experimental and laboratory studies

All comparative laboratory tests were performed in a pilot scale ball mill loaded with various ball media to treat the two different size feed samples. Pilot scale ball mill having 120 cm Ø × 60 cm dimension run at constant operating conditions [mill speed of 31.0 rpm, volumetric charge of 30%, feed material of 163 kg and ball charge of 952 kg]. Four different ball loads set as the identical to standard Bond ball mill load were used during the tests.

Same kinds of clinker having different size distributions were used as the feed material. Finenesses of them are given in Table 1. Feed samples were initially ground batchwise and representative sample taken from inside the mill during the definite intervals of time which are 2, 5, 10, 15, 20 and 30 minutes. Then the particle size distributions of these samples were characterized. In addition, Bond ball mill work index of 12.31 kWh/t was determined with standard Bond ball mill grindability test. Some tests regarding the investigation of the effects of ball size and hardness on grinding kinetics were conducted as well.

Table 1
Finenesses of both feed samples used in grinding tests

	100% passing size [mm]	80% passing size [mm]
Coarse size feed material	25.40	1.70
Fine size feed material	1.70	0.43

Results and discussion

The variation of the particle size distributions of products versus grinding time in two different tests are shown in Figure 1. The results of tests which remain can be seen at *Erdem* [2] study. Particle size distributions in each test became finer regularly through grinding time. These figures indicated that determination of the specific rate of breakage would be possible.

It can be seen that coarser particles of both feed samples showed rapid disappearance in the tests performed by ball load in which 50 mm top size ball diameter. On the contrary, coarse particles retained in the test performed using coarse size feed material and ball load in which 20 mm top size ball diameter in spite of the fact that grinding time was extended up to 20 minutes, which is not unusual grinding time for industrial application. It can be said that broken particle size depend on optimum ball size in ball loads because of having different breakage mechanism of different size balls. This phenomenon may indicate that coarse ball media offer a larger probability for impact breakage and cause to rapid disappearance of coarser particles in the feed.

Using the particle size distributions of feed and mill content the grinding process in ball mill was modelled with *Whi-*

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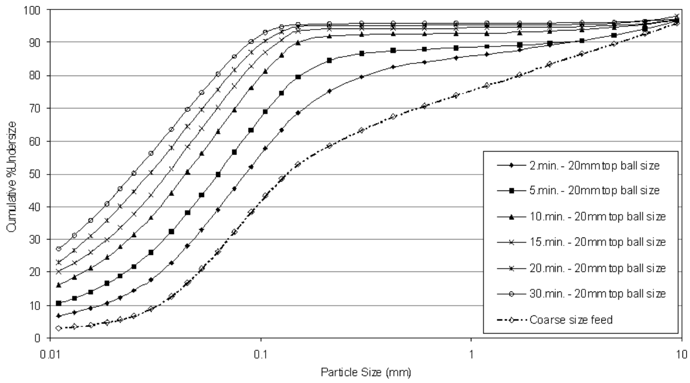
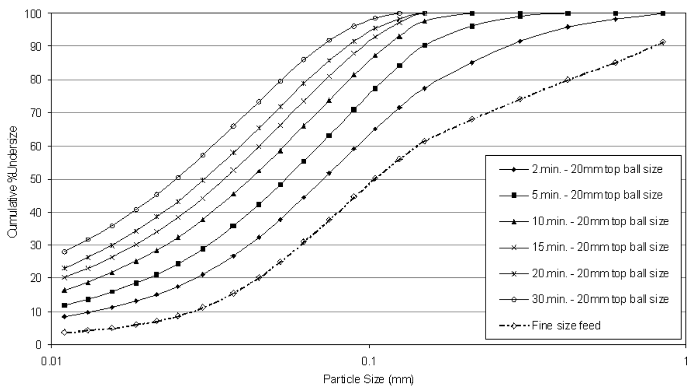


A - Particle size distribution of product with ball media in which 20 mm top ball size (Coarse feed)



B – Particle size distribution of product with ball media in which 20 mm top ball size (Fine feed)

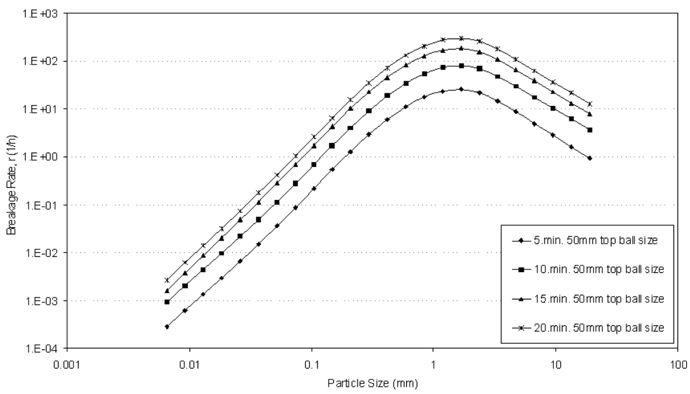
Fig. 1. Obtained particle size distributions of mill content versus grinding time using coarse and fine size feed material under ball load in which 20 mm top size ball diameter

ten's [6] perfect mixing model given in Equation 1 and the breakage rate parameter (r/d) of each size fraction were back calculated for each test.

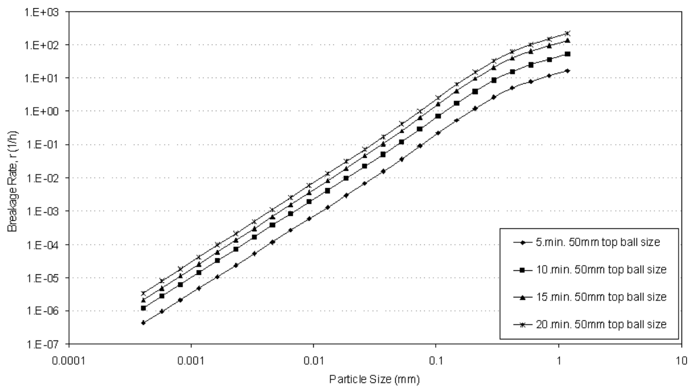
$$f_i - r_i \frac{p_i}{d_i} + \sum_{j=1}^{i} a_{ij} r_j \frac{p_j}{d_j} - p_i = 0 \tag{1}$$

In this equation, f and p are fraction of material in the feed and product, respectively (tph), r is breakage rate of particles (1/h), d is discharge rate of particles (1/h), r/d is breakage rate parameter and a_{ij} is breakage function.

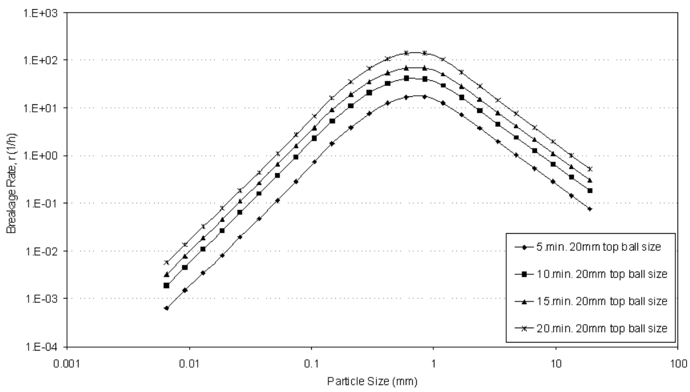
The changes of breakage rate versus particle size through the grinding time in four tests are shown in Figure 2. The results of other four tests performed using ball load in which 40 mm and 30 mm top size ball diameter can be found at *Erdem* [7] study. The difference between breakage rate of particles at 10 minutes of tests conducted using two different size feed materials under four different ball loads are given in Figure 3. Finding results show that the breakage rate increases with increasing particle size of feed up to a certain size and then it decreases with increasing particle size of feed. Fine grinding media produces faster breakage rates



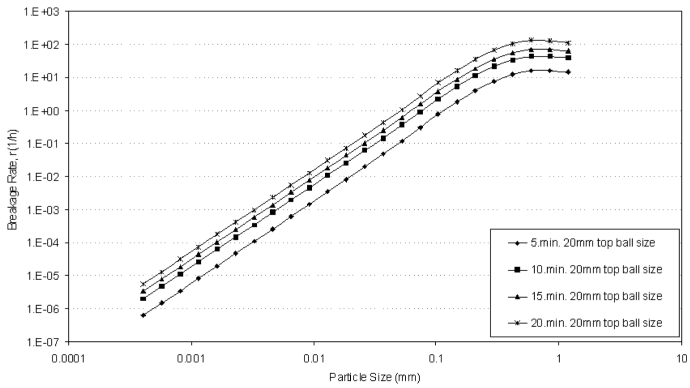
A - Breakage rate of material in the test of ball media in which 50 mm top ball size (coarse feed)



C - Breakage rate of material in the test of ball media in which 50 mm top ball size (fine feed)



B - Breakage rate of material in the test of ball media in which 20 mm top ball size (coarse feed)



D - Breakage rate of material in the test of ball media in which 20 mm top ball size (fine feed)

Fig. 2. The variation of breakage rate with particle size during grinding time in grinding media tests performed using coarse and fine size feed sample

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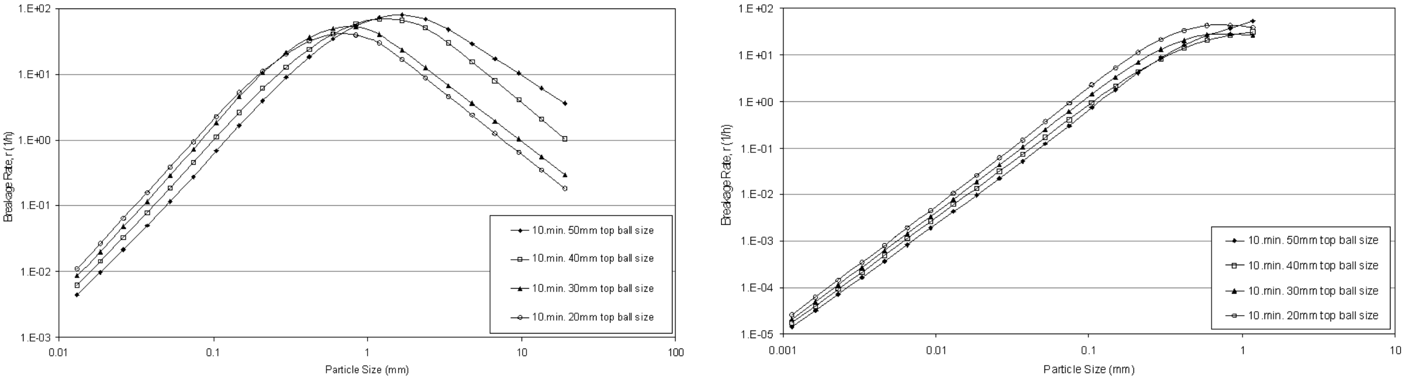


A - Breakage rate of material at 10 min. of tests (coarse size feed) **B - Breakage rate of material at 10 min. of tests (fine size feed)**

Fig. 3. The variation of breakage rate with particle size for 10 min. of grinding tests performed by four different ball loads and two different size feed sample

than coarse grinding media up to a certain size then start going inversely under the same condition. The difference between the breakage rates of particle size at which maximum breakage occurs in each grinding test is more significant.

Figure 4 and 5 show the obtained result when breakage rate (r) and feed size (X) are normalized by r_m and X_m. r_m is the maximum value of breakage rate and X_m is the optimum feed size at which the grinding rate takes maximum value. It is clearly seen that the relationship between the dimensionless grinding rate, r/r_m, and the dimensionless feed size, X/X_m, can be expressed by a convex curve and its fit is fairly well. The tendency in the variation of breakage rate values with particle size takes a similar pattern irrespective of top ball size. However, there is an optimum feed size at which breakage rate takes a maximum value and this particle size at maximum breakage occurs is dependent of top ball size. So it is strongly associated with optimum ball size.

The variation of breakage rate of different size feed sample at 10 min. of tests under different ball loads is given in Figure 6 to be seen the effect of particle size on grinding parame-

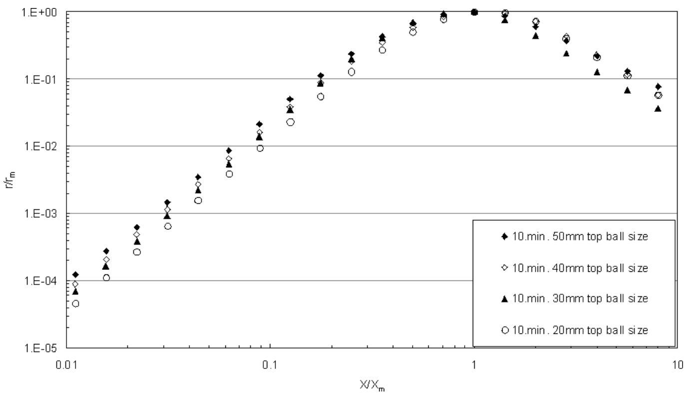


Fig. 4. Variation of dimensionless breakage rate with dimensionless coarse size feed material for 10 min. of tests

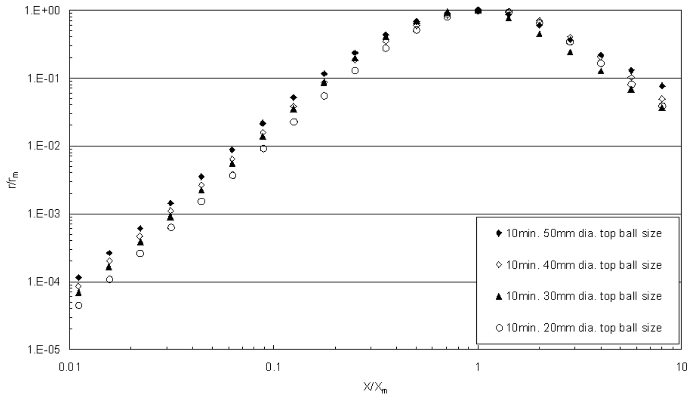
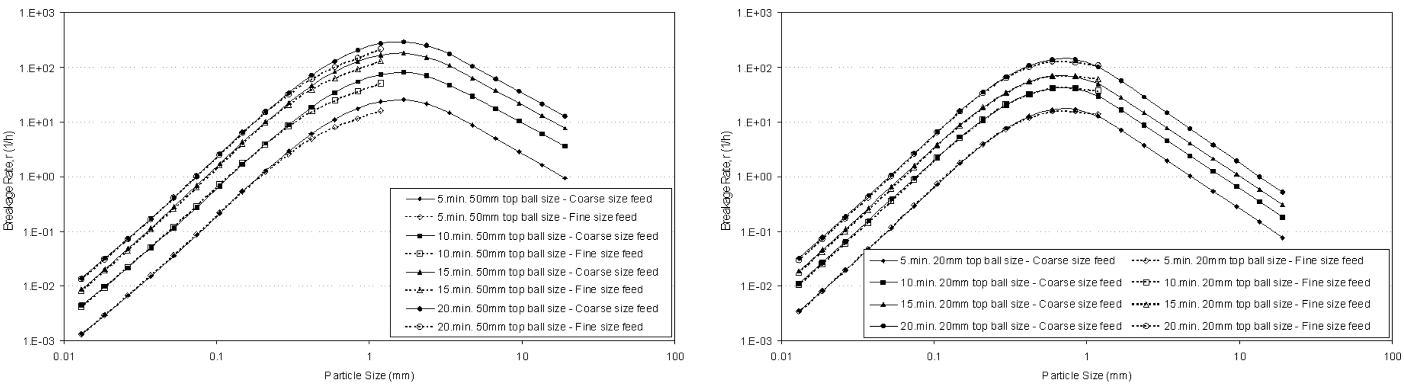


Fig. 5. Variation of dimensionless breakage rate with dimensionless fine size feed material for 10 min. of test



A - Breakage rate of coarse and fine size feed materials in the test with 50mm top size ball load **B - Breakage rate of coarse and fine size feed materials in the test with 20 mm top size ball load**

Fig. 6. Breakage rate of particles during grinding time of tests performed with different ball loads in which 50 mm and 20 mm top size ball diameter and two different size feed sample

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ters. The obtained result clearly shows that particle size and optimum ball diameter determine the shape of breakage rate graph and they are significant parameters influencing the grinding kinetics in ball mill.

Conclusions

The major point of the research program was what the effect of ball size, particle size and material hardness on grinding kinetics is. In this study the effect of particle size on grinding kinetic was explained with data collected from a pilot scale ball mill. The obtained results clearly show that particle size and optimum ball diameter determine the shape of breakage rate curve and it takes a similiar pattern irrespective of ball size but particle size at maximum breakage occurs is dependent on top ball size. Consequently, the feed particle size is strongly related to top ball size in ball media and they are significant parameters influencing the grinding kinetic in ball mill. This topic needs further study and experimental verification to provide more data to explain the relationship between particle size and breakage rate in detail and install a correlation in numerical.

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