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Effect of Feed Rate on Comminution Products by Fractal Geometry

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ABSTRACT: The effect of feed rate on the particle size distribution of crushing products was investigated by fractal dimension. The particle size distribution was calculated based on the cumulative particle weight to particle size ratio. An evaluation has been made between laboratory results and the fractal model by the root mean square error (RMSE) method. A comparison between fractal geometry and Rosin-Rammler methods has been made for the particle size distribution description. The comminution of the ore was performed by three-jaw, cone, and roll crushers. Each of the crushers was fed with rates of 0.5, 1, 1.5, 2, 3, 4, and 4.5 kilograms per minute. The fractal dimension of the particle size distribution for jaw, cone, and roll crushers was (from 2.18 to 2.32), (from 2.12 to 2.27), and (from 2.30 to 2.43), respectively. The smallness of the fractal dimension of the particles crushed by the cone crusher is due to the uniformity of product particles. The bigness of fractal dimension of the materials crushed by roll crusher is due to the limited range of particle sizes. The limited range of particle sizes causes the uniformity of product weight distribution. A 2 mm opening sieve was selected as a target sieve, from which the weight percentage of the passing particles to the post-crushing stage was calculated. The results show that by increasing the feed rate, the amount of material passing from the target sieve is decreased. The RMSE, in the fractal model, for jaw, cone, and roll crushers were obtained (between 7.87 and 9.31), (between 3.50 and 4.17), and (between 0.83 and 2.62), respectively. The RMSE results, in the Rosin-Rammler method, for jaw, cone, and roll crushers were obtained (between 7.87 and 9.31), (between 3.50 and 4.17), and (between 0.83 and 2.62), respectively. Based on the results, for the particle size distribution description, the fractal geometry is a quantitative and more suitable manner than the Rosin-Rammler method.

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1- Introduction

The feed rate is one of the effective parameters in ore crushing, stabilizing the operation. The amount of required production is achieved by the feed rate control [1]. The feed rate is affected by the energy consumption and dispersion of particle size distribution [2]. The comminution may account for 30-50% of the total cost in mineral processing operations [3]. About 3% of the total energy consumed in the world is spent on comminution operations, only 1% of which is used properly for comminution [4]. The amount of crushed material can be examined by the particle size distribution. Logarithmic diagrams are the most common way of displaying the particle size distribution [5, 6]. Fractal geometry is a statistical method in which the particle size distribution of fragmented ores can be quantified by calculating their fractal dimensions [7]. The finer the particle size, the greater the fractal dimension [8]. The fractal dimension of the crushed particle size distribution depends on the ore type, the amount of energy consumption, the comminution mechanism, and the input feed particle size [9].

2- Materials and Methods

2.1. Material

The studied sample was copper ore, with a particle size of (-50 +16) mm, obtained from Ghalezari mine, Khorasan province, Iran. The minerals constituting the ore can be sorted as quartz, microcline, kaolinite, talc, chlorite, and chalcopyrite based on their frequencies. The chemical analysis indicated a CuO content of 0.64%, on which the stoichiometry calculations showed a grade of 1.5 % for chalcopyrite content in the sample.

2.3. Fractal Dimension Calculation

To calculate the fractal dimension, a correlation can be established between the size and cumulative weight of the particles, as Eq. (1) [10-14]:

$$\frac{M\,(k<K_L)}{M_T}=c\left(\frac{k}{K_L}\right)^{3-D_f} \tag{1}$$

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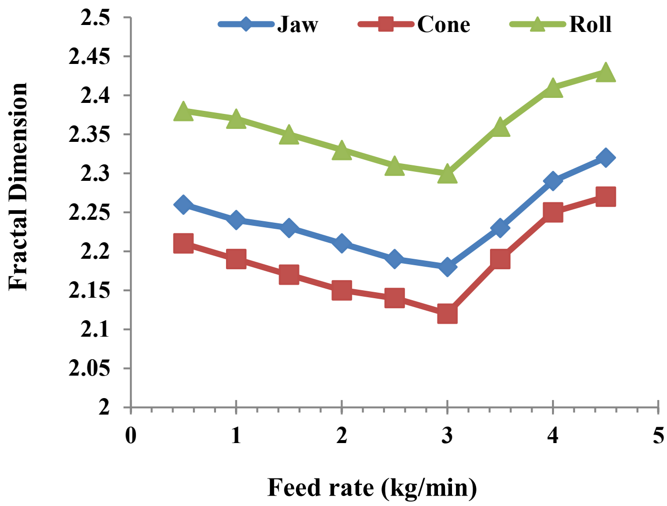

Fig. 1. Fractal dimension variations of crushing products relative to feed rates

where M, M_T, k, K_L, and D_f are the cumulative particle weights passing the defined fractions, the total weight of the particles, the size of the defined fraction, the size of the largest fraction, and the fractal dimension, respectively. Taking the logarithm of Eq. (1) yields Eq. (2), by which D_f can be obtained as:

$$Ln\frac{M(K_L > k)}{M_T} = (3 - D_f)Ln(\frac{k}{K_L}) + Lnc \qquad (2)$$

2.3. Rosin Rammler (R-R)

The R-R distribution is a conventional method for the particle size distribution description, as given in Eq. (3) [15]:

$$\frac{100}{W_r} = \exp[(\frac{x}{x'})^b] \qquad (3)$$

Where x is the screen aperture size, W_r is the cumulative mass (in %) retained on size x, x' is the size parameter, and b is a measure of the spread of particle sizes. Small and large values of b indicate scattered and uniform distributions, respectively [16, 17].

3- Results and Discussion

The feed rate influences the comminution efficiency. The fractal dimension of the particle size distribution was calculated using Eq. (2). The fractal dimensions for jaw, cone, and roll crushers of the feed rates of 0.5, 1, 1.5, 2, 2.5, 3, 4, and 4.5 kg/min were obtained (as 2.18-2.32, 2.12-2.27, and 2.30-2.43), respectively. An increase in the feed rate in the permitted capacity reduces the fractal dimension (D_f), while D_f is increased by an increase in the feed rate in unpermitted capacity. There is usually a direct relationship between the dispersion rate of particle size distribution and the fractal dimension.

In jaw and cone crushers, the Rosin-Rammler index b increases with increasing the feed rate at the permitted capacity, becoming the particle size distribution of the crushed products more uniform. However, the index b is decreased with the feed rate reaching the maximum capacity (from 3.5 kg/min upwards), thereby increasing the dispersion of the particle size distribution. In the case of roll crusher, this index is decreased at the permitted capacity and increased in the unpermitted capacity.

Fig. 1 shows the fractal dimension variations of crushing products relative to feed rate.

4- Conclusion

The results of this research can be summarized as follows:

The fractal dimensions for the crushed product particles are between 2.12 and 2.43, being under the general principles of fractal geometry related to the particle size distribution (to be between 2 and 3).

As the feed rate increases at the permitted capacity of the crushers, the fractal dimension of the products decreases due to the reduced dispersion of the particle size distribution and the reduced particle size of the crushed fine particles, having an inverse relationship between the feed rate at the permitted capacity and the fractal dimension of the crushed product.

As the feed rate is exceeded the permitted capacity of the crushers, the fractal dimension of the products is increased due to the choke feeding, by creating a significant amount of fine, soft, and irregular particles. Therefore, there is a direct relationship between the feed rate in the unpermitted capacity and the fractal dimension of the particles.

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