A New Model on Breakage Behaviour of A Laboratory Impact Mill

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ABSTRACT: In this study, the breakage behavior of three different limestones in impact crushers using common in quarry and mineral processing plants was investigated. The laboratory horizontal shaft impact mill used in the experiments is rotating at 2840 rpm, which driven by a 1.1 kW motor, carries three rows of hammers. In the evaluation of crushers, *t-family* curves obtained used from weight drop test method are frequently used. It is known fact that there are many difficulties and problems in this test. A new model is developed by *t-family* value evaluation and Bond work index approach, and this model is tested. As a result it is determined that the limestone properties are important in crushing and the validity of the model is proved by a high regression value (1^=0.88).

1 INTRODUCTION

Energy necessity is very high in crushing and grinding process. There are many crusher manufactures and many varieties of machines made for crushing minerals. The correct selection between all alternative is a difficult problem.

Impact-induced rock fragmentation is relevant for many fields of science and technology. Impact mills have been applied in mineral, coal and cement industries for a long time. The literatures show that substantial effort has been expended in understanding the impact mill performance in relation to machine configuration and operational conditions through experimental work and mathematical modelling. However, due to lack of detailed knowledge on velocity and energy distributions of collision inside a milling chamber, the mechanisms are still not clear (Djordjevic et al, 2003).

Single particle tests to determine the comminution behaviour of ore can be separated into pendulum and drop weight based tests. Twin pendulum test relies on the particle being broken between an input pendulum released from a known height and a rebound pendulum. The drop weight test differs in that the particles are placed on a hard surface and struck by a falling weight. Both these approaches have been used extensively in field of comminution. In recent years, the drop weight apparatus are being replaced by twin pendulum. The standard drop weight device is fitted with a 20 kg mass, which can be extended to 50 kg. The effective range of drop heights is 0.05 to 1.0 m, which represents a wide energy range from 0.01 to 50 kWh/t (based 10-50 mm particles). Following sample preparation the mean mass of each set of particles to be broken is calculated. The results from the drop weight tests provide an energy/input size/product size relationship. This relationship is analysed using a set of curves to describe the size distribution produced from breakage events of increasing size reduction or energy input (Bearman et al, 1997).

Narayanan and Whiten (1998) have widely used a novel procedure for estimation of breakage distribution functions of ores from the so-called *t-family* of curves. In this method, the product size distribution can be represented by a family of curves using marker points on the size distribution defined as the percentage passing(f) at a fraction of the parent particle size. Thus, *h* is the percentage passing an aperture of half the size of the parent particle size, *U* is one quarter and *tig* is one-tenth of parent particle size. They have proposed empirical equations for relating the reference curve data *tjo* with the impact energy.

The t_n versus *tig* relationships can then be used to predict the product size distributions at different grind times (Sand & Subasinghe, 2004).

The *tjo* value is related to the specific comminution energy by the equation:

$$t_{m} = A\{l-e^{-bE''}\} \quad (1)$$

where,

tio= percentage passing 1/10 of the initial mean size,

Ecs= specific comminution energy (kWh/t)

A,b= ore impact breakage parameters

In the drop weight test, a known mass falls through a given height onto a single particle providing an event that characterisation of the ore under impact breakage. Although, the drop weight test has advantages in terms of statistical reliability and the potential use of the data from the analysis, it has a number of disadvantages, particularly the length of time taken to carry out a test. For each drop weight test, 15 samples are tested in 5 size fractions at 3 levels of energy input (Kingman et al, 2004).

In this study, breakage behavior of three different limestones in a laboratory impact crusher was investigated. It is known fact that there are many difficulties and problems in drop weight test method. A new model is developed by *t-family* value evaluation and Bond work index- approach, and this model is tested.

2 MATERIALS AND METHOD

2.1 Material

Three different limestone samples taken from different region of Turkey were used as the experimental materials. The chemical properties of the limestone samples are presented in Table 1.

Table 1. Chemical composition of limestone samples used in experiments

Oxides (%)	Limestone I	Limestone II	Limestone III
CaO	31.03	46.85	48.99
SiO_2	0.05	8.45	10.60
Al2O3	0.90	1.02	1.07
Fe_2O_3	0.00	0.35	0.59
MgO	22.42	0.92	1.11
SO3	0.02	0.07	0.09
Na_2O	0.07	0.02	0.04
K_2O	0.10	0.06	0.08
L.O.I	45.24	36.50	38.72

2.2 The test of Standard ball mill Bond grindability

The standard Bond grindabüity test is a closed-cycle dry grinding and screening process, which is carried out until steady state condition is obtained. This test was described as follow (Bond and Maxson, 1943; Yap et al., 1982; Austin and Brame, 1983; Magdalinovic, 1989):

The material is packed to 700 cc volume using a vibrating table. This is the volumetric weight of the material to be used for grinding tests. For the first grinding cycle, the mill is started with an arbitrarily chosen number of mill revolutions. At the end of each grinding cycle, the entire product is discharged from the mill and is screened on a test sieve *(Pi)*. Standard choice for *P-,* is 106 micron. The oversize fraction is returned to the mill for the second run together with fresh feed to make up the original weight corresponding to 700 cc. The weight of product per unit of mill revolution, called the ore grindability of the cycle, is then calculated and is used to estimate the number of revolutions required for the second run to be equivalent to a circulating load of 250%. The process is continued until a constant value of the grindability is achieved, which is the equilibrium condition. This equilibrium condition may be reached in 6 to 12 grinding cycles. After reaching equilibrium, the grindabilities for the last three cycles are averaged. The average value is taken as the standard Bond grindability ($Q_{,g}$).

The products of the total final three cycles are combined to form the equilibrium rest product. Sieve analysis is carried out on the material and the results are plotted, to find the 80% passing size of the product *(Pi)*. The Bond work index values *(Wi)* are calculated from the equation below.

$$W_i = 1.1 * \frac{44.5}{P_i^{0.23} * G_{bg}^{0.82} * \left[\left(10/\sqrt{P_{80}}\right) - \left(10/\sqrt{F_{80}}\right)\right]} \quad (2)$$

Wi : Bond's work index, (kWh/1)

P, : screen size at which the test is performed (106 Uni)

Gb_g : Bond's standard ball mill grindability, net weight of ball mill product passing sieve size Pj produced per mill revolution, (g/rev)

P_8o and F_8o- sieve opening which 80% of the product and the feed passes, (|xm)

3 EXPERIMENTS

Firstly, Standard Bond's grindability tests were made for three limestone samples. Results of tests, Bond grindability values of limestone samples were appeared 6 14 g/rev, 1 69 g/rev and 1 54 g/rev, Bond work index values were calculated 4 44 kWh/t, 10 10 kWh/t and 13 53 kWh/t, respectively Then, the laboratory horizontal shaft impact mill, rotating at 2840 rpm, driven by 1 1 kW motor, carry three rows of hammers, were used in the experiments One kilogram sample of six mono size fractions (-6 7+4 75, -4 75+2 8, 2 8+1 7, -1 7+1 18, 1 18+0 600, -0 600+0 355 mm) were piepared and crushed in a laboratory scale impact mill for determination of the *t-family* curves Each sample was taken out of the impact mill and sieved product size analysis

Results of *t family* curves versus mean size fraction for there different limestone are shown in Figure 1 3

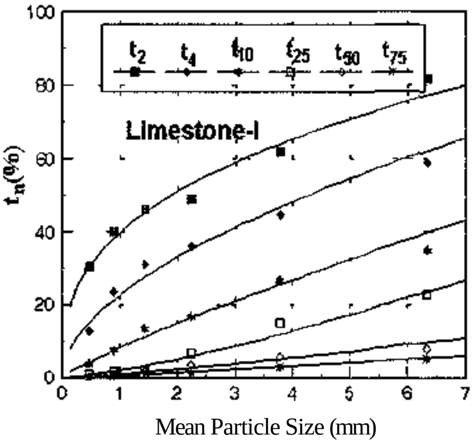

Figure 1 *t„* versus mean size fraction for hmestone-I

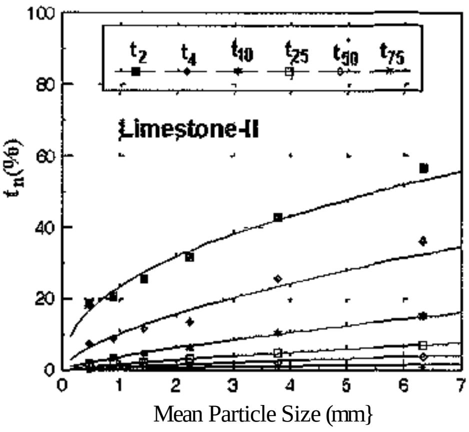

Figure 2 /„ versus mean size fraction for limestone-II

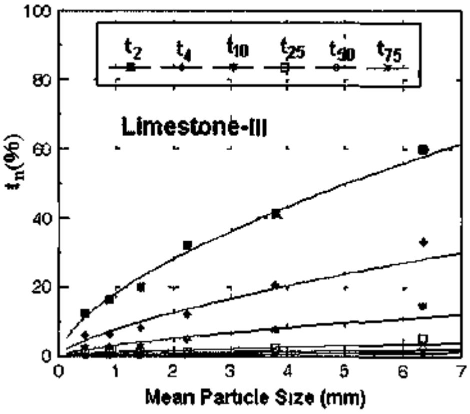

Figure 3 *t„* versus mean size fraction for limestone-III

4 PROPOSED MODEL

Narayanan and Whiten (1998) that the cumulative fraction of products passing 1/«* of the mean size was denoted by *t„* It was also reported that this relationship was applicable to different ore types tested under different impact loading conditions A similar relationship has been observed *t„* values for crushing products m the direct laboratory impact mill and forms the basis of the proposed model

In this work, the relationship between the cumulative percentage passing *ifw)* with Bond's work index *(W,)* and mean feed size(X) was empirically described by Eq (3)

$$t_n = \frac{406.35}{W_i^{0.921} * n^{1.1}} X^{0.108 W_i^{0.668} * n^{2.47 W_i^{-1.184}}} \quad (3)$$

where,

(„ the cumulative percentage passmg(l/nth) of the mean particle size (%)

W, Bond's work index of limestone (kWh/t)

X Mean particle size (mm)

The experimental values and the calculated results obtained by Eq (3) were compared in Figure 4 Eq (3) mostly satisfies the experimental values m a wide range of feed size, and Eq (3) is useful especially when evaluating the particle size proportion in the actual operation by a high regression value (r^2=0 88)

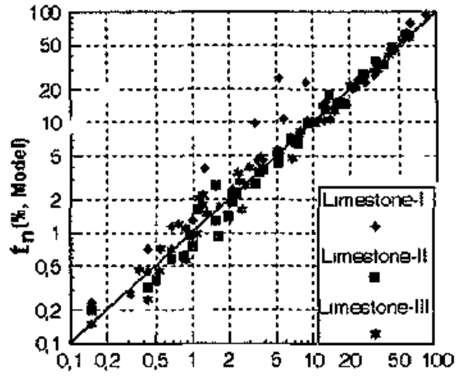

Figure 4 Comparison of experimental and calculated t_n value for limestone

SCONCLUSIONS

In this study, laboratory crushing tests of three different limestones with an impact mill were carried out The effects of mean particle size and Bond's work index of limestones on product size distribution were investigated

The results showed that limestone-I sample was more friable than limestone-II, which was more friable than limestone-III A set of *t-curves* were calculated from the laboratory impact mill, and a new model was developed

Obtaining *t-family* values from drop weight apparatus is time consuming and difficult The mathematical mode impact crusher results, is found to be more appropriate m determining t-family values than drop weight apparatus.

There are not many studies on the effects of rotor speed, lining design, hammer design and feed dose of limestone in impact crushers, which are used in quarries and mineral processing plants. For this purpose, similar mathematical models should be developed for different work parameters for various materials and various crusher types

REFERENCES

Austin, L G and Brame, K, 1983 A comparison of the Bond method for sizing wet tumbling mills with a size-mass balance simulation method *Powder Technology* Vol 34 261-274

Bearman, RA, Bnggs, CA, Kojovıc, T, 1997 The application of rock mechanics parameters to the prediction of comminution behaviour *Minerals Engineering* Vol 10 255-264

Bond, FC and Maxson, WL, 1943 Standard gnndabihty tests and calculations *Trans SME-AIME* Vol 153 362-372

Djordjevic, N, Shi, FN, Morrison, RD, 2003 Applying discrete element modelling to vertical and horizontal shaft impact crushers *Minerals Engineering* Vol 16 983-991

Kingman, S W , Jackson, K, Cumbane, A , Bradshaw, S M , Rowson, N A , Greenwood, R , 2004 Recent developments m microwave in microwave-assisted comminution *hit Journal of Mineral Processing* Vol 74 71-83

Magdalinovic, N, 1989 A procedure for rapid determination of the Bond work index *hit Journal of Mineral Processing* Vol 27 125-132

Narayanan, S S , Whiten, WJ , 1988 Determination of comminution characteristics from single particle breakage tests and its application to ball mill scale-up *Trans Inst Min Metall (Section C)* Vol 97 115-124

Sand, G W, Subasınghe, G K N, 2004 A novel approach to evaluating breakage parameters and modelling batch grinding *Minerals Engineering* Vol 17 1111-1116

Yap, RF, Sepulude, JL and Jauregui, R, 1982 Determination of the Bond work index using an ordinary laboratory batch ball mill *Design and Installation of Comminution Circuits* A L Mular (Co-Editor) Soc Mm Eng *AIME,* USA 176 -203