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Study of Bond work index (Wi) using a laboratory-scale rod mill

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ABSTRACT:

The design of a crushing mill is influenced by the material properties (hardness), desired product size, operating conditions (mill speed) and energy efficiency. This Study focuses on the specific energy consumption and how much energy is required to reduce the size of the material. Here it is also analyzed that the energy required to grind a material i, e. work index of the material that can be found experimentally by performing grinding tests and applying Bond's formula. The work index is crucial because it directly influences the design of crushing and grinding equipment.

Key Words: Bond Working Index (BWI), Rod Mill, Crushing Energy.

Introduction:

The Work Index (BWI) is an empirical metric that quantifies the energy needed to reduce particle size during crushing and grinding processes in ore dressing processing. It was developed by Fred Chester Bond and is used to estimate the energy needed to grind a material in a ball or rod mill. It is expressed in kilowatt-hours per ton (kWh/ton).It provides a comparative measure of the material’s resistance to crushing and grinding. It is used to calculate the required energy to reduce a particle to a specified size, allowing engineers to design more efficient mills and optimize their operation.

Literature review:

A more practical approach for evaluate the power needed for crushing and grinding, based on Bond's law, is given by the formula:

$P/M = Kb / \sqrt{Dp}$ ----------1

Where: Kb is Bond's constant, which depends particle characteristic to be crushed

D p is the size of particle in mm

P represents the power in KW

M is the rate of mass flow in metric tons per hour.

Bond's constant Kb is determined through the material's work index (Wi), defined as the total required energy (in KW-hours per ton) to reduce a large particle size to a point where 80% of the product particles can pass through a 0.1 mm screen. Therefore based on this definition we can write that if, $D = \infty$ and $Dp = 0.1$mm then $E/M = Wi$ kwh/ton

This definition establishes a relationship between Kb and Wi.

$Wi = Kb/\sqrt{0.1}$

$Kb = \sqrt{0.1} Wi = 0.316 * Wi$ -----------2

When 80% of the feed particle passes through a mesh size of Dfa mm, and 80% of the product particle passes through a mesh size of Dpb mm, from the equations 1 and 2 we get:

$P/M = 0.316 * Wi\ (1/\sqrt{Dpb} - 1/\sqrt{Dfa})$ -----3

Rod Mill Set up:

Experimental Study:

A limestone sample is prepared by grinding it to a size smaller than 5 mesh (3.35 mm). The feed is thoroughly sieved using a sieve shaker for 25 minutes. The sieves used for size distribution are 10, 22, 30, 44, 52, 60, 100, and pan. The mass of material retained on each sieve is recorded to measure the size distribution of the feed.

A total of 1500 g of the material is placed in a rod mill bowl (with a 5 kg capacity) along with 5 rods, each having a diameter of 25.4 mm and a length of 300 mm. The mill operates for 25 minutes at a speed of 57 rpm. After milling, the product is sieved for 25 minutes using the same set of sieves (10, 22, 30, 44, 52, 60, 100, and pan). The mass of material retained on each sieve is measured to determine the size distribution of the product.

A graph is plotted between the mass fraction (cumulative) and the aperture size (in mm), from which the 80% passing size for both the feed and product is obtained.

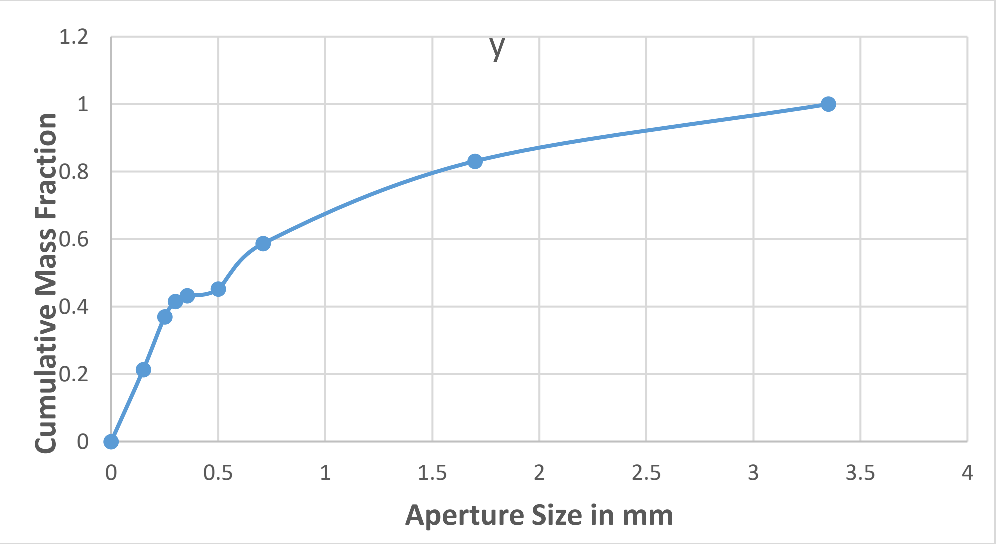
The power consumed by the mill under no-load conditions is 0.515kw (as measured by the energy meter), and the power consumed under load conditions is 0.53kw. Therefore, the actual power required for crushing is P = 0.015kw.

Observation Table:

FEED ANALYSIS:

Mesh No. #	Aperture Size in mm	Mass retain on sieve in gm	Mass fraction in gm	Cumulative mass fraction in gm
5	3.35	0	0	1
10	1.7	255	0.17	0.831
22	0.71	366	0.244	0.587
30	0.5	202	0.135	0.452
44	0.355	30	0.02	0.432
52	0.3	25	0.017	0.415
60	0.25	68	0.045	0.37
100	0.15	235	0.157	0.213
PAN	0	319	0.213	0

Graph for feed analysis:

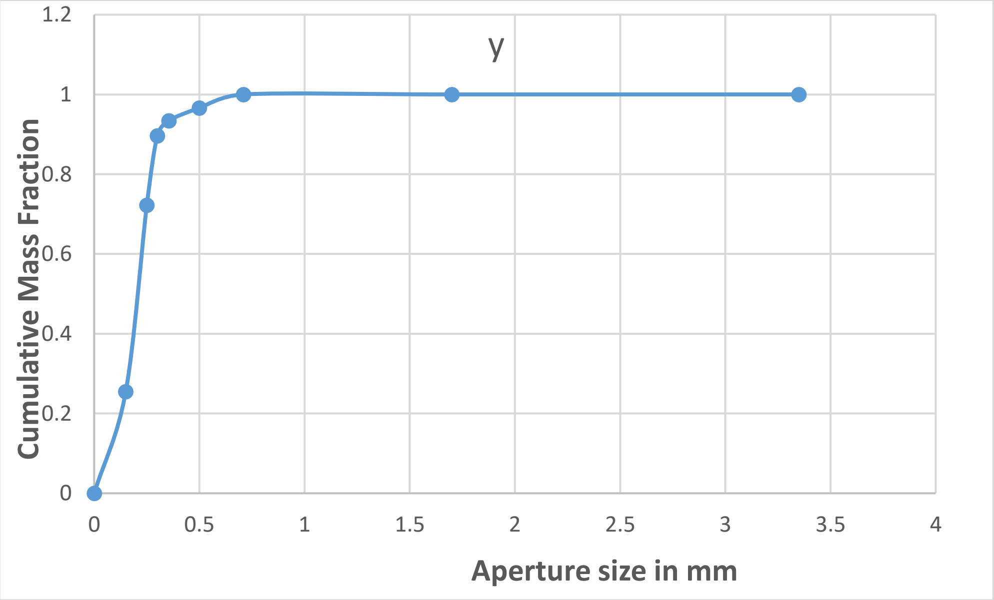


From graph Df80 = 1.55 mm

PRODUCT ANALYSIS:

Mesh No. #	**Aperture Size in mm**	**Mass retain on sieve (Product) in gm**	**Mass fraction (Product) in gm**	**Cumulative mass fraction (Product) in gm**
5	3.35	0	0	1
10	1.7	0	0	1.0009
22	0.71	1	0.0007	1.0002
30	0.5	51	0.0342	0.966
44	0.355	47	0.032	0.934
52	0.3	56	0.038	0.896
60	0.25	260	0.174	0.722
100	0.15	696	0.467	0.255
PAN	0	380	0.255	0

Graph for product analysis:



From graph Dp80 = 0.3 mm

Calculation:

Df80= 1.55, Dp80= 0.3, time = 25 minute = 0.417hr, mass of feed = 1500gm = 0.0015 mt

Power at no load = 0.515kw , power at load = 0.53kw

Specific power consumption for crushing = (0.53-0.515) = 0.015kw

From the equation P/M = 0.3162*Wi(1/√Dpb - 1/√Dfa)-----3

Wi = 12.89 KWh/mt

Conclusion:

In summary, bond work index is an important metric in mineral processing and milling, allowing engineers to estimate energy requirements and design more efficient crushing and grinding mills. Here in this study, in a laboratory rod mill, the energy required to crush limestone material is 12.89 kWh/mt. This Index facilitates comparison of energy efficiency across different milling and grinding operations and serves as a guide for designing comminution mills to optimize the crushing and grinding stages.

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