18/'" International Mining Congress and Exhibition of Turkey-IMCET2003, <ö 2003, ISBN 975-395-605-3

The Effect of Circulating Load and Test Sieve Size on The Bond Work Index Based on Natural Amorphous Silica

V. Deniz. N. Sütçü & Y. Umucu
Department of Mining Engineering Süleyman Deınirel University, İsparta, Turkey

ABSTRACT: Bond work index is being widely used to estimate power required to grind materials. Because grindability is so widely used in mill design the assumption is often made that the method is valid without a sufficiently critical examination of the associated uncertainties, which can lead to large contingency factors in design. Too large an energy contingency factor can lead to a drive motor having to be operated at such a fraction of maximum load that a considerable efficiency penalty is invoked. Hence the problems of grindability inaccuracies are important.

In this study, the effect of circulating load (CL) and test sieve size (P,), which are inaccuracies of Bond grindability, on the Bond ball mill grindability (G_{hg}) and work index (W,) are investigated based on four samples of natural amorphous silica.

In the experimental studies, the relationships between the Bond work index with circulating load and test sieve size were examined.

I INTRODUCTION

Currently, silica fume is widely used as a supplementary cementing material to enhance the strength and durability of concrete. Concrete containing silica fume has yielded higher compressive strengths, increased sulfate and acid resistance, and decreased chloride permeability in many applications. Amorphous silica possessed many physical and chemical properties similar to those of silica fume (Anderson et al. 2000).

Diatomaceous rocks are sedimentary rocks of biogenic origin with high natural amorphous silica (NAS) content. The amorphous silica is mainly in the form of diatom frustules, and secondarily in the form of sponge spicules, silicone-flagcllate skeletons and/or radiolarian cells. Beside its amorphous silica contenl, diatomite rocks may also contain carbonate and clay minerals, quartz, feldspars and volcanic glass (Fragoulis et al. 2002).

Amorphous silica is widely used as filtering agent, special fillers, absorbents, insulation product and a supplementary cementing material etc. In these industries, ultra fine grinding of amorphous silica is needed.

In the design of grinding circuits in a mineral processing plant, the Bond method is widely used for a particular material in dimensioning mills, power needs and the evaluation of performance. Its use as an industrial standard is very common as a result of providing satisfactory result in the all-industrial applications. Despite having many advantages, this method has some drawbacks such as its tiring and long test time as well as it needs a special mill. Due to these difficulties, recently a number of easier and faster methods are developed to determine Bond work index (Berry&Bruce 1966, Smith&Lee 1968. Karra 1981, Yap et al 1982, Armstrong 1986: Magdalinovic 1989, Deniz et al 1996. Deniz&Özdağ 2003).

Austin&Brame (1983) and Austin et al.(1984) have summarized the problems with the Bond grindability as circulating load, effects of test sieve size, classifier effectiveness, the optimum mixture of ball size in the charge, variation of the residence time distribution of particles with mill geometry and slurry density, lifter design, slurry rheology(wet milling), it is assumed that specific energy is not a function of ball load contrary to known fact, only the 80% passing size is considered, no account is taken of over-filling or under-filling of the mill, cause of inefficiency in grinding are not explored.

Smith and Lee (1968) and Tuziin (2001) are investigated variation of test work index with test sieve size for some materials. They showed that the Bond work index increased as the finer sieve size. Magdalinovic (1989) showed that Bond work index is not a validation with test sieve size for 100 to 500 micron of P„

Armstrong (1986) investigated variation of the Bond work index with different circulating loads for puritic ore, calculated Bond work index is higher with different circulating loads, the Bond work index is higher with lower circulating loads.

The purpose of this study to determine the effects of circulating load (CL) and test sieve size (P;) on the Bond ball mill grindability (G_{ht},) and work index (W,) with natural amorphous silica.

2 MATERIAL AND METHOD

As a base for this study, four natural amorphous silica samples were used for test. The chemical properties of samples are presented in Table 1. Firstly, weigh out 25 kg samples taken from a representative composite of feed to be analyzed. Stages crush the feed so that 100% passes a 3.36 mm screen. Cone and quarter the feed, using a riffle splitter, to recover a representative 600 g head sample. The crude feeds were split into representative smaller batches, which were oven dried at 105 °C. The air-pyenometer densities of four natural amorphous silica were 2.35, 2.28, 2.27 and 2.27 g/cm , respectively. The bulk densities of samples were 0.77, 0.65, 0.72 and 0.74 g/cm^3. Secondly, Standard Bond grindability tests were done for three different test sieve size (150, 106 and 63 microns) and four different-circulating load (100%. 250%. 400% and 550%), and work indexes (W,) were calculated.

2.1. The test of standard ball mill Bond grindability

The standard Bond grindability test is a closed-cycle dry grinding in a standard ball mill (30.5x30.5 cm) and screening process, which is carried out until steady state condition is obtained. This test was described as follow (Bond&Maxson 1943, Yap et al. 1982, Ausiin&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, (he entire product is discharged from the mill and is screened on a test sieve (P,). 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 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 grindabilitics for the last three cycles are averaged. The average value is taken as the standard Bond grindability ($G_{h!:}$).

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 (P,).

Table I. Chemical composition of amorphous silica samples used in experiments

Oxides (%)	1	II	111	IV
SiO,	92.22	87.75	92.41	91.27
Al.O,	0.04	0.10	0.00	0.32
TiO,	0.14	0.12	0.09	0.12
Fe_20,	0.40	0.02	0.00	0.02
CaO	0.57	0.25	0.02	0.60
Na.O	0.05	0.10	0.01	0.11
K,0	0.07	0.03	0.03	0.10
SO,	0.61	0.21	0.08	0.18
Loss on ignition	4.40	5.21	4.77	5.40

3 EXPERIMENTS

3.1 Bond grindability test

The samples taken, are crushed in a laboratory scale jaw crusher and standard Bond grindability test is performed. Work index values (W,) are calculated from equation below.

$$W_i = 1.1 * \frac{44.5}{P_i^{0.23} * G_{bg}^{0.82} * \left[\left(10/\sqrt{P_{80}}\right) - \left(10/\sqrt{F_{80}}\right)\right]} \quad (1)$$

W, : work index, (kWh/t)
P, : sieve size at which the test is performed ((.tm)
Ghj. : Bond's standard ball mill grindability, (g/rev)
Pxn . FK»: sieve opening which 80% of the product and feed passes, respectively (<im).

For each samples, G_{hs}, and W, values are given in Table 2.

Table 2. The values of G_{hf} and Wi for samples of Natural Amorphous Silica

			I		II		III		IV	
No.	P_i (μm)	CL %	G_{bg} g/rev	W_i kWh/t	G_{bg} g/rev	W_i kWh/t	G_{bg} g/rev	W_i kWh/t	G_{bg} g/rev	W_i kWh/t
1	150	100	2.091	11.11	2.066	11.41	1.627	12.99	1.895	11.89
2	150	250	2.911	8.94	3.297	8.05	2.272	10.78	2.055	10.83
3	150	400	3.047	8.52	3.720	7.05	2.386	10.28	2.450	10.07
4	150	550	3.247	8.12	4.036	6.51	2.639	9.61	2.737	9.19
5	106	100	1.454	13.77	1.307	14.62	1.239	14.95	1.349	14.30
6	106	250	1.958	11.44	1.858	11.94	1.739	12.67	1.584	13.16
7	106	400	2.095	11.18	2.709	9.25	1.823	12.16	1.759	12.42
8	106	550	2.195	10.75	3.143	8.24	1.951	11.53	1.927	11.77
9	63	100	0.755	18.11	0.679	19.16	0.652	19.45	0.688	19.07
10	63	250	1.216	14.62	1.095	15.88	1.051	15.88	I.II0	15.48
11	63	400	1.360	13.40	1.567	11.93	1.405	13.11	1.282	14.66
12	63	550	1.516	12.25	1.807	10.50	1.505	12.37	1.476	12.38

3.2. Correlation found from the test results

3.2.1. Effect of circulating load on Bond's work index

Figures 1-3 shown variation in the Bond work index with circulating load. It has been found thai the calculated work index is increased with lower circulating loads for each test sieve size. Otherwise, effect on the Bond work index is mostly for the finer test sieve size (63 micron).

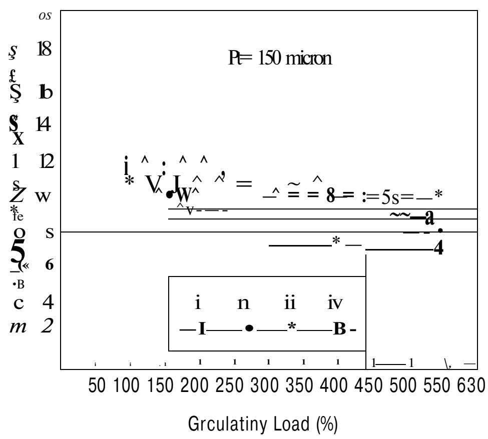


Figure I. Variation of Bond work index with circulating load lbrP,= 150 micron

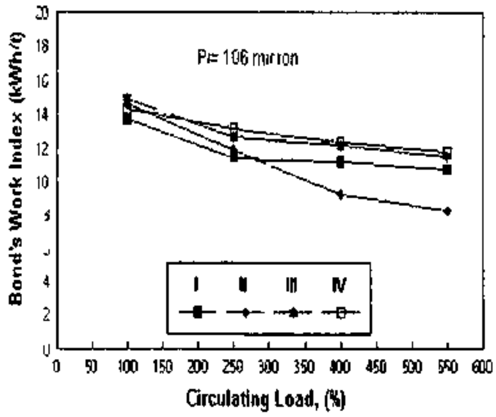
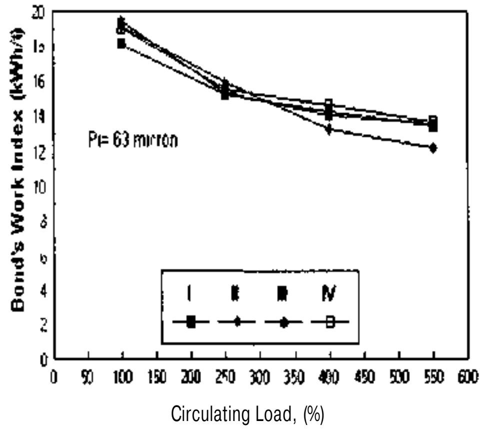


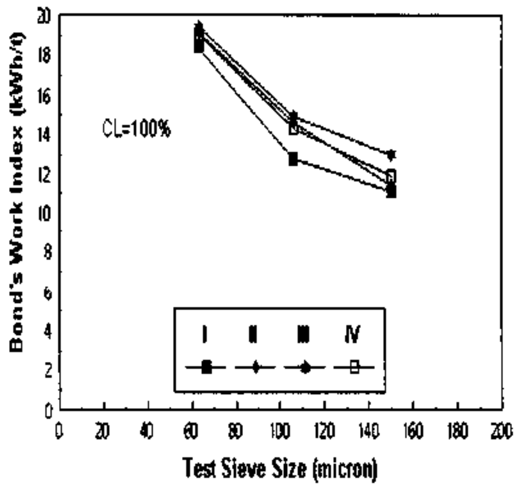
Figure 2 Vanation ot Bond work index with cuculating load loi P = 106 micion



Fıguıe 1 Vanation of Bond woik index with uiuilating load loi Pi=6^ mitron

3 22 Effect of diffeient test siexe size on Bond's w oik index

Fıguıes 4-7 shown vanation in the Bond woik index with tcsl sieve size As test iesulls, The Bond woik index mueased as the liner sieve si/e was used Espesiuilly, Bond woik index more mueased in 63 mm on as the emulating load was 100%



Fıguıe 4 Vaııatıon ot Bond woik index with the test sieve sı/etoı CL= 1000î

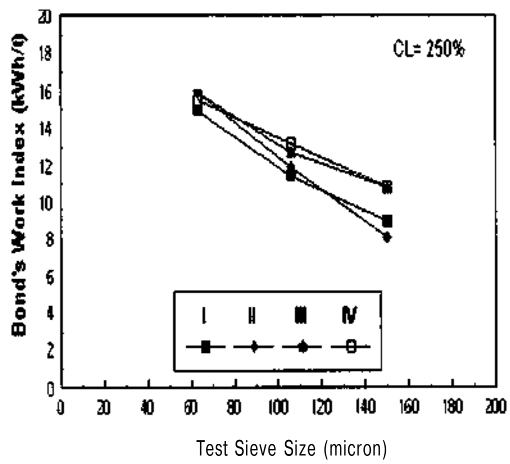


Figure S Vanation of Bond woik index with the test sitve si/e loi CL= 250'/

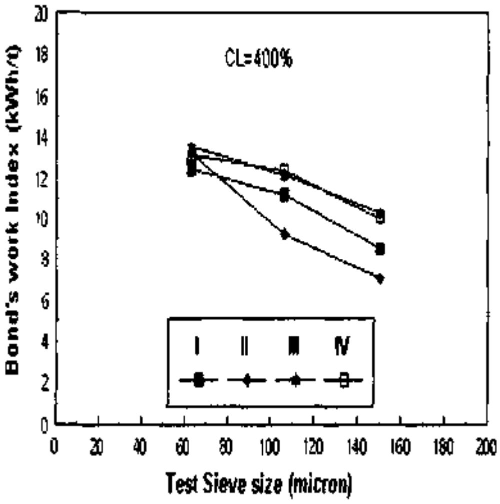


Figure 6. Variation of Bond work index with (he test sieve size for CL= 400%

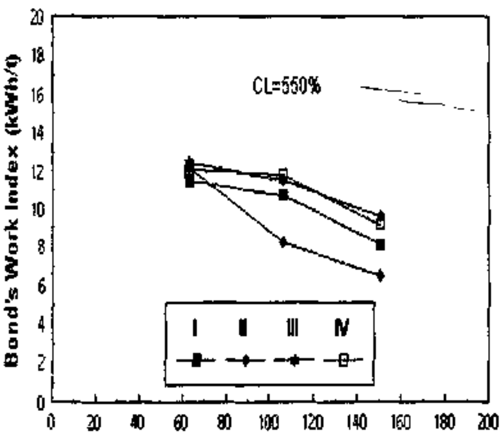


Figure 7. Variation of Bond work index with the lest sieve size for CL= 550'/

4 CONCLUSIONS

The present investigations have shown that a relationship could be established between the Bond's work index with circulating loads and lest sieve size.

The conclusions from the test can be summarized as follows.

1) The Bond's work index values increased as test sieve si/.e decreased.
2) The Bond's work index values increased as circulating load decreased.
3) Bond work index is changed with the change in ihe test sieve size and circulating load. This must be taken inlo account when energy consumption is calculated according to the Bond formula.
4) Bond work index is changed with the change in materials properties. Contents SiOi of sample II is lower than other samples. Hence, Bond work index value of sample II is lover than other samples
5) In grinding of amorphous silica, unit energy cost extra increased as circulating load decreased from 250%. However, unit energy cost decreased as circulating most suitable circulating load for amorphous silica used experiments is 250%.
6) III trail nc grinding, although, unit energy cost is possibility decreased with circulating load increased (higher 250%). However, mill capacity is decreased.

REFERENCES

Andeison. D.. Roy. A.. Seals. R.K.. Carlledge. F.K.. Akliler H and Jones S.C..2002. A preliminary assessment of the use of an amorphous silica residual as a supplementary cemenlary cementing material. *Cement and Concrete Research.* Vol. 30. 473-445.

Armstrong. D.G..I986. An alternative gnndability test: An improvement of (lie Bond procedure. *Int. ./. nf Mm. Praıcssiıu;.* Vol. 16. I"7-208.

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

Austin. L.G.. Klimpel. R.R. and Luckie. P.T..I984. Process Engineering of Size Reduction: Ball Milling. *SME-AIME.* NewYoik. USA.

Beiiy. T.F. and Bruce. R.W.1%6. A simple method ot determining the grindabihty of ores. *Can. Min. J.* Vol. 87. 63-65.

Bond. F.C. and Maxson. W.L,. 1943. Standard gnndability tests and calculations. *Trans. Sac. Min. Eng. AIME.* Vol. 153.362-372.

Deniz V Balta Ci and Yanıık A 19% riıc ınlcıiclatıonshıps between Bond gıındahıhls ot loals and impact stıengtlı index (ISI) point load index (Is) and Pliability index (F|>) *Cinimi/uf;* S<»/JM *m Minimi Pitnewint;* Kemal et al (hdilois) A A Balkema Roteidam Nelheilands li-19

Dem/ V and Odag H 2003 A new approach Bond gıındabılıty and woik index Dynamic elastic paıameteıs *Muuıuh k/ıvifietııiK* (ınpıess)

hagoulıs D Stamatakıs M Papageoıgıou D Pentelenyj L and Csıık G 2002 Dıatomaccous eaıth as a cement additive A cast study ol deposits lıom Ninth eastein Hungaiv and Milos Island Gieece */KU limrnatwmil* Vol Si 8l1 Hi

Kana V K I9SI Simulation ot Bond gıındabılıty tests *CIM Bull* Vol 74 I9S-199

King M S 1983 Static and dynamic elastic pıoptıtıes ot locks from the Canadian Shield *lut J Rink Mali Mm* Sil Ä<«i«iiir/i *Aim,* Vol 20 217-24S

Magdahnovic N 1989 Calculation ot energy requited foi gnnding in a Ball mill *hit I of Mm Pun twin/;* Vol 2'> 41-46

Magdalmmic N 1989 A pioceduie toi lapid determination ot the Bond Woik Index *lui I of Mm Pimi-umn* Vol 27 I2VI12

Smith RW and I ee KH 1968 A companson ot data tiom Bond type simulated closed eiicuit and batch type gıındabılıty tests 7*;«;» *Sin Mm bııf AIME* Vol 241 91 99

Tu/un MA 2001 Wet Bond Mill Test *Mimnih lımımcııiK* Vol 14 169 171

Yap R F" Sepulude II and lauiegui K 1982 Deteinnnation ot the Bond Woik Index using an ordinary laboıatoıy batch ball mill *DL* we« *ami lıtsttılltıtum nj ı nmmmuliim ı mints* LG Austin (Fditoi) SMK AIME NewYoik 176-201