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Technical Faculty in Bor
Mining and Metallurgy
Institute Bor

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PROCEEDINGS

Editors:
Ljubiša Balanović
Dejan Tanikić

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PREFACE

On behalf of the Organizing Committee, it is a great honor and pleasure to welcome all esteemed participants of the **56th International October Conference on Mining and Metallurgy (IOC 2025)**, scheduled to take place at **Bor Lake, Serbia**, from **October 22nd to 25th, 2025**.

The collaborative efforts of the University of Belgrade – Technical Faculty in Bor and the Mining and Metallurgy Institute Bor have once again brought together academia, industry, and research institutions to organize this year's IOC. Our focus remains firmly set on presenting the latest research achievements and technological advancements in geology, mining, metallurgy, materials science, technology, environmental protection, and other engineering disciplines.

This year's conference program is rich and diverse, featuring **4 plenary lectures, 4 invited lectures, 158 full papers, and 6 abstracts**. The proceedings reflect the contributions of authors from **19 countries**: Austria, Bosnia and Herzegovina, Bulgaria, Canada, China, Croatia, Germany, Hungary, India, Mexico, Montenegro, Poland, Romania, Russia, Serbia, Slovakia, Slovenia, Turkey, and the United Kingdom. Among the submitted papers, eight young researchers under the age of 35 have qualified to participate in the "**MDPI Young Researcher Award**" competition, further emphasizing the conference's commitment to supporting and recognizing excellence among the new generation of scientists and engineers.

We are also delighted to host the **9th International Student Conference on Technical Sciences (ISC 2025)**, running in parallel with IOC 2025. The student conference brings together young researchers from Serbia and the wider region, with **one plenary** and **50 student papers** presented, offering an invaluable opportunity for the next generation of scientists and engineers to share their ideas and discuss the future of their disciplines with experts. The "**Professor Dragana Živković Best Student Paper Award**" will be presented to the most outstanding student contribution based on originality, research quality, and presentation.

The Organizing Committee expresses its deepest gratitude to all who have supported this event. Our General Sponsor is the Ministry of Science, Technological Development, and Innovation of the Republic of Serbia. We are especially grateful to our Platinum Donors, HBIS Serbia and Serbia Zijin Mining, as well as our Gold Sponsor, DPM Metals Inc., and our Gold Donors, Copper Mill Sevojno and Serbia Zijin Copper Bor. This year, the conference is also supported by the Silver Donor, "MC LABOR" d.o.o. Beograd.

We proudly host a diverse exhibition, featuring Indemak, Labtim SE d.o.o., MERIS d.o.o., Krug International LTD, Altium International d.o.o., Metalurg Foundry Ltd., Fugro Germany Land GmbH, Analysis d.o.o., Lola institut, Tescan and Mikrolux d.o.o., Trokuttest Serbia, Novos d.o.o., Changsha Rui Rui Technology Co., Ltd., and the Winery of Bukovo Monastery. The official opening of the conference has been supported by Epiroc Srbija a.d.. Finally, we warmly acknowledge our Friends of the Conference: Messer Tehnogas AD Belgrade, the China-Serbia Joint Laboratory on Green Steel Manufacturing, and the Foundation B.Sc. Eng. Boško Injac.

We sincerely thank all authors, committees, reviewers, speakers, and chairpersons for their invaluable contributions to shaping IOC 2025. We are confident that the conference will once again serve as a alive platform for scientific exchange, professional networking, and the promotion of sustainable development in mining, metallurgy, and related fields.

On behalf of the 56th IOC Organizing Committee,
Prof. dr Ljubiša Balanović

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Original scientific paper

REFINEMENT OF THE BOND WORK INDEX CALCULATION METHOD FOR FINER SAMPLES

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Abstract

The Bond work index (BWI) is a widely recognized method used for selecting comminution equipment, evaluating grinding efficiency, and calculating the required grinding power. Although it is considered an industry standard, Bond did not fully define all steps in his original procedure, which can lead to significant variability in test results. One such undefined aspect is the initial particle size of the test material-specifically, the commonly used 3.35 mm feed size. This raises the question of whether the BWI can be reliably determined using finer samples. In practice, materials with particle sizes smaller than 3.35 mm are often encountered. This study continues previous research by examining whether the proposed model for calculating the BWI on fine samples is applicable to medium-hard ores. The validation of the model on medium-hard samples resulted in an error of less than 1%, confirming its high accuracy.

***Keywords**: Bond Work Index, Finer Samples, Grindability.*

1. INTRODUCTION

The BWI is a fundamental parameter used to assess the grindability of materials and to estimate the energy requirements in comminution processes. It has long been considered a standard tool in the mining and mineral processing industries for the selection, sizing, and evaluation of grinding equipment. The BWI is determined through a laboratory procedure that simulates closed-circuit grinding under standardized conditions, typically using material with a starting particle size of 3.35 mm.

However, in real industrial and laboratory conditions, raw materials are often available in finer samples, which introduces practical limitations to the standard Bond procedure. Since the original method was not fully defined in terms of input sample characteristics, particularly particle size distribution, there is a growing interest in adapting the procedure for finer samples. The ability to accurately determine the BWI from such materials would provide greater flexibility in testing and expand the method's applicability to a wider range of industrial scenarios. [1]

Several recent studies have proposed modifications to the traditional Bond method to accommodate finer samples, often involving recalibrated test conditions, energy calculations, or mathematical models. These alternative approaches aim to maintain the reliability and reproducibility of results while enabling the analysis of materials that fall outside the standard testing range.

This study builds upon a previously developed method for calculating the BWI using fine samples. The main objective is to evaluate the extended applicability of this approach, with a focus on maintaining accuracy and consistency in grindability assessment, regardless of initial particle size.

Levin (1989) [2] developed a method for assessing the grindability of fine samples based on the evaluation of the energy required for their comminution, primarily applied in ball milling. Later, Magdalinović et al. (2012) [3] adapted the determination of the BWI for samples of non-standard particle sizes, achieving a method accuracy with an error of less than 5%. Nikolić and Trumić

(2021) [4] investigated the possibility of determining the BWI for fine samples. They proposed a model for calculating the BWI of fine samples based on the known value for a standard particle size sample. Their study was conducted exclusively on a zeolite sample, yielding an error of less than 2.5%. The present study continues this line of research to examine whether the proposed model can also be applied to medium-hard samples.

2. EXPERIMENTAL

In mineral raw material comminution practice, samples with particle sizes smaller than -3.35 mm are frequently encountered, raising the question of whether the standard Bond method can be applied to such fine samples for the determination of the BWI. Bond (1961) [5] did not explicitly address this situation; instead, his standard grindability test requires that all samples must have an initial particle size below -3.35 mm, but provides no guidelines for cases where samples are already finer than this threshold at the outset. In such instances, the assessment of grindability may rely solely on data obtained from existing industrial plants, which can be used to estimate the BWI. However, this approach is limited, as it requires access to operational data and is often not feasible under laboratory conditions. Therefore, there is a growing need to develop methodologies that enable reliable determination of the BWI for fine samples. To date, only a limited number of researchers have addressed this issue, and the literature lacks systematic studies on the subject. The present study focuses precisely on this open problem, aiming to explore the possibilities for determining the BWI on finer samples.

The testing was conducted on a dacite sample, using different particle size classes: -3.35 + 0 mm; -2.36 + 0 mm; -1.70 + 0 mm; -1.18 + 0 mm; and -0.850 + 0 mm (particle size distribution (PSD) presented in Table 1 and Figure 1). A 75 μm closing screen size (P100) was used. The BWI is calculated using Equation (1).

$$W_i = 1.1 \cdot \frac{44.5}{{P_{100}}^{0.23} \cdot G^{0.82} \cdot \left(\frac{10}{\sqrt{P_{80}}} - \frac{10}{\sqrt{F_{80}}} \right)} \quad (1)$$

where in:

P_{100} - closing screen size (μm),
G - net mass of undersize product per unit revolution of the mill, in g/rev,
P_{80} - the 80% passing product particle size (μm),
F_{80} - the 80% passing feed particle size (μm).

Table 1. Dacite sample PSDs

Particle Size (mm)	Class size in mm (%)				
	- 3.35 + 0	- 2.36 + 0	- 1.70 + 0	- 1.18 + 0	- 0.850 + 0
- 3.35 + 2.36	27.77				
- 2.36 + 1.70	15.60	21.08			
- 1.70 + 1.18	12.59	18.24	23.42		
- 1.18 + 0.850	7.99	11.28	14.83	17.54	
- 0.850 + 0.600	7.52	10.18	12.98	16.40	20.91
- 0.600 + 0.425	6.10	8.28	10.36	13.47	16.02
- 0.425 + 0.300	5.45	7.39	8.76	11.94	14.62
- 0.300 + 0.212	4.05	5.46	6.73	9.21	10.95

- 0.212 + 0.150	3.39	4.57	5.55	7.76	9.25
- 0.150 + 0.106	2.08	3.00	3.78	5.46	5.93
- 0.106 + 0.075	1.77	2.39	2.92	3.68	5.02
- 0.075 + 0.00	5.69	8.13	10.67	14.54	17.30
∑	100.00	100.00	100.00	100.00	100.00

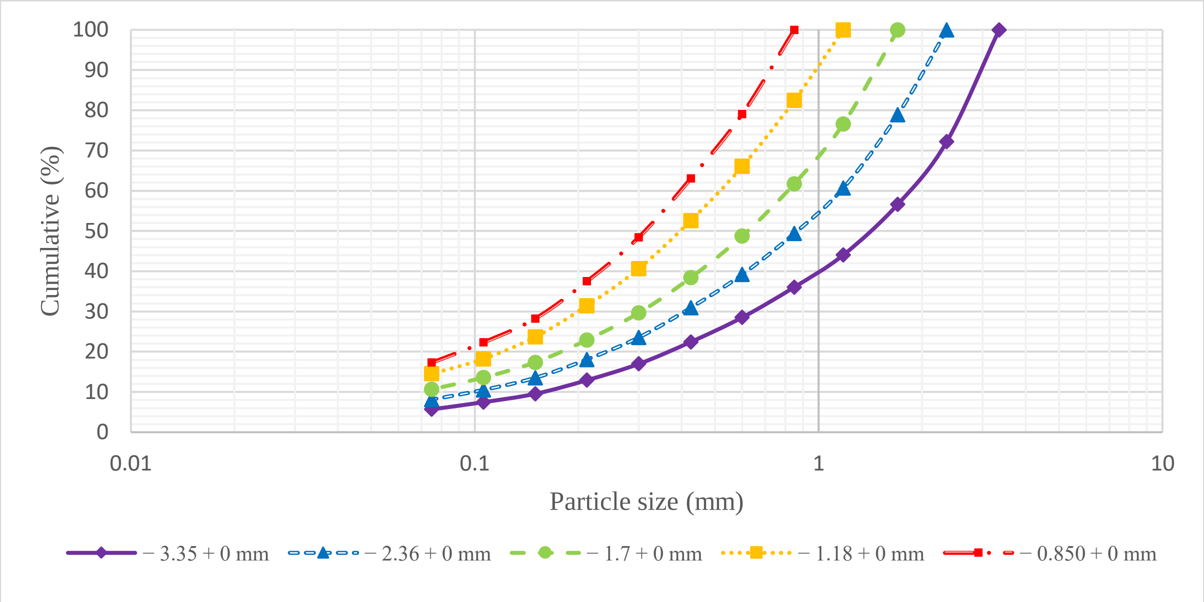

Figure 1. Dacite sample PSDs

3. RESULTS AND DISCUSSION

The results of determining the grindability on a samples of dacite on fine size classes are shown in Table 2.

Table 2. Parameters F_{80}, P_{80}, G and value of Wi for finer size classes

Sample	Size (mm)	F_{80} (µm)	P_c=75 µm		
			P_{80} (µm)	G (g)	Wi (kWh/t)
Dacite	- 3.35 + 0	2646	64.70	0.96	17.800
	- 2.36 + 0	1729	64.76	1.00	18.130
	- 1.70 + 0	1253	65.76	1.05	18.333
	- 1.18 + 0	807	65.20	1.10	18.827
	- 0.850 + 0	609	65.64	1.12	19.196

Nikolić and Trumić (2021) [4] proposed a model for calculating the BWI for finer samples (Equation 2), based on the grindability test results of a zeolite sample. The authors emphasized that Equation (2) was tested exclusively on a zeolite sample, which is classified as a soft ore. In the present study, Equation (2) was also tested on a dacite sample in order to determine whether the proposed model can be applied to medium-hard ores as well.

$$W_{Fm} = k \cdot \frac{W_i}{{F_{Fm}}^{0.05}} \qquad (2)$$

where in:

W_{Fm} - BWI for fine materials, (kWh/t);
W_i - BWI for a standard size sample (- 3.35 + 0) mm, (kWh/t);

F_{Fm} - the 80 % passing fine material particle size, (μm),
k - coefficient whose value is $(k = 1.47)$.

When Nikolić and Trumić (2021) [4] presented their model for calculating the BWI for finer samples, based on a zeolite sample, the coefficient k was determined to be 1.47. However, when the model was tested on a dacite sample, it was observed that this coefficient k is not constant, but varies with the hardness of the sample. For medium-hard ores, the value of the coefficient k was found to be $(k = 1.48)$. The results of testing Equation (2) on the dacite sample are presented in Table 3.

Table 3. Comparative results obtained experimentally and using the Eq. (2).

Sample	Size (mm)	F_{80} (μm)	$P_c = 75$ μm			
			W_i (kWh/t)	k	W_{Fm} (kWh/t)	Error Δ (%)
Dacite	- 3.35 + 0	2646	17.800	1.48	-	-
	- 2.36 + 0	1729	18.130		18.146	- 0.88
	- 1.70 + 0	1253	18.333		18.441	- 0.60
	- 1.18 + 0	807	18.827		18.851	- 0.13
	- 0.850 + 0	609	19.196		19.118	+ 0.41

The results of testing the defined model indicate that the difference between the Bond Work Index values obtained by computational and experimental methods is very small-less than 1%. Such a result confirms the high reliability of the model. It was also established that when the model is applied to moderately hard samples, the coefficient value $(k = 1.48)$ should be used.

4. CONCLUSION

The research presented in this paper demonstrates that the proposed model for calculating the (BWI) using finer samples can be successfully applied not only to soft ores, as previously verified, but also to medium-hard materials. The comparison between experimentally obtained BWI values and those calculated by the model revealed very small deviations, generally below 1%, which confirms the high accuracy and reliability of the method. Furthermore, it was established that the coefficient k, is not constant but varies depending on the hardness of the tested material. For medium-hard ore, the appropriate coefficient value was determined, ensuring that the model provides consistent and precise results. Further research will include the verification of the model on very hard samples.

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