University of Belgrade
Technical Faculty in Bor,
Mining and Metallurgy
Institute Bor

54th International October Conference on Mining and Metallurgy

PROCEEDINGS

Editors:
Ljubiša Balanović
Dejan Tanikić

18-21 October 2023, Bor Lake, Serbia

PROCEEDINGS,

54th INTERNATIONAL OCTOBER CONFERNCE

on Mining and Metallurgy

Editors:

Prof. dr Ljubiša Balanović

Prof. dr Dejan Tanikić

University of Belgrade, Technical Faculty in Bor

Technical Editor:

M. Sc. Miljan Marković

University of Belgrade, Technical Faculty in Bor

Publisher: University of Belgrade, Technical Faculty in Bor

For the publisher: Dean Prof. dr Dejan Tanikić

Circulation: 200 copies

CIP - Каталогизација у публикацији Народна библиотека Србије, Београд

622(082)(0.034.2)
669(082)(0.034.2)

INTERNATIONAL October Conference on Mining and Metallurgy (54 ; 2023 ; Borsko jezero)
Proceedings [Elektronski izvor] / 54th International October Conference on Mining and Metallurgy - IOC 2023, 18-21 October 2023, Bor Lake, Serbia ; [organized by] University of Belgrade, Technical Faculty in Bor and Mining and Metallurgy Institute Bor ; editors Ljubiša Balanović, Dejan Tanikić. - Bor : University of Belgrade, Technical Faculty, 2023 (Niš : Grafika Galeb). - 1 USB fleš memorija ; 1 x 1 x 5 cm

Sistemski zahtevi: Nisu navedeni. - Nasl. sa naslovne strane dokumenta. - Tiraž 200. - Preface / Ljubiša Balanović. - Bibliografija uz svaki rad.

ISBN 978-86-6305-140-9

a) Рударство -- Зборници b) Металургија -- Зборници

COBISS.SR-ID 126659849

Bor Lake, Serbia, October 18-21, 2023

Conference is financially supported by
The Ministry of Science, Technological
Development and Inovation
of the Republic of Serbia

Platinum Donors

ZIJIN SERBIA ZIJIN MINING

ZIJIN SERBIA ZIJIN COPPER DOO

SEVOJNO VALJAONICA BAKRA COPPER MILL

Gold Donors

HBIS GROUP HBIS SERBIA

Dundee PRECIOUS METALS AVALA

Silver Donor

trokuttestgroup

Exhibitions

Labtim

Altium

metalurg

MERIS

1969 ZAJEČAR FMT

REFRATEC

Friends of the Conference

DONAU LAB BEOGRAD

DONCAFÉ

LOLA INSTITUT

THE FOUNDATION 'B.SC. ENG. BOŠKO INJAC'

SCIENTIFIC COMMITTEE

Prof. Dr Dejan Tanikić *(Serbia) - president*
Prof. Dr Nada Štrbac *(Serbia) - vice-president*
Prof. Dr Radoje Pantović *(Serbia) - vice-president*

Dr Ana Kostov *(Serbia)*
Prof. Dr Adam Grajcar *(Poland)*
Prof. Dr Adina Negrea *(Romania)*
Dr Andrei Rotaru *(Romania)*
Prof. Dr Batrić Pešić *(USA)*
Dr Biserka Trumić *(Serbia)*
Prof. Dr Boštjan Markoli *(Slovenia)*
Dr Branislav Marković *(Serbia)*
Prof. Dr Cornelia Muntean *(Romania)*
Prof. Dr Daniela Grigorova *(Bulgaria)*
Prof. Dr Dejan Ivezić *(Serbia)*
Prof. Dr Desimir Marković *(Serbia)*
Prof. Dr Dimitris Panias *(**Greece**)*
Prof. Dr Dimitriu Sorin *(Romania)*
Prof. Dr Dmitry Vasilyev *(Russia)*
Dr Dragan Komljenović *(Canada)*
Prof. Dr Dragan Manasijević *(Serbia)*
Dr Dragan Milanović *(Serbia)*
Prof. Dr Dragan Milovanović *(Serbia)*
Prof. Dr Dragoslav Gusković *(Serbia)*
Prof. Dr Dušan Oráč *(Slovakia)*
Prof. Dr Duško Minić *(Serbia)*
Prof. Dr Endre Romhanji *(Serbia)*
Prof. Dr Essen Suleimenov *(Kazakhstan)*
Prof. Dr Farzet Bikić *(Bosnia and Herzegovina)*
Prof. Emeritus Fathi Habashi *(Canada)*
Prof. Dr Grozdanka Bogdanović *(Serbia)*
Prof. Dr György Kaptay *(Hungary)*
Prof. Dr Ivan Mihajlović *(Serbia)*
Prof. Dr Iveta Vaskova *(Slovakia)*
Prof. Dr Jakob Lamut *(Slovenia)*
Prof. Dr Jasmin Suljagić *(Bosnia and Herzegovina)*
Dr Jasmina Stevanović *(Serbia)*
Dr Jasna Stajić Trošić *(Serbia)*
Prof. Dr Jovica Sokolović *(Serbia)*
Prof. Dr Jožef Medved *(Slovenia)*
Prof. Dr Kaikun Wang *(China)*
Prof. Dr Karl Heinz Spitzer *(Germany)*
Prof. Emeritus Karlo Raić *(Serbia)*
Prof. Dr Kemal Delijić *(Montenegro)*
Prof. Dr Komnitsas Konstantinos *(Greece)*
Prof. Dr Kostas Matis *(Greece)*
Prof. Dr Krzysztof Fitzner *(Poland)*
Prof. Dr Luis Filipe Malheiros *(Portugal)*
Prof. Dr Milan Antonijevic *(Serbia)*
Prof. Dr Milan Trumić *(Serbia)*
Dr Mile Bugarin *(Serbia)*
Dr Milenko Ljubojev *(Serbia)*
Prof. Dr Milovan Vuković *(Serbia)*
Prof. Dr Mira Cocić *(Serbia)*
Mirjam Jan-Blažić *(Slovenia)*
Prof. Dr Mirjana Rajčić Vujasinović *(Serbia)*
Prof. Dr Mirko Gojić *(*Croatia*)*
Dr Miroslav Sokić *(Serbia)*
Prof. Dr Mirsada Oruč *(Bosnia and Herzegovina)*
Dr Nadežda Talijan *(Serbia)*
Prof. Dr Natalija Dolić *(*Croatia*)*
Prof. Dr Nedeljko Magdalinović *(Serbia)*
Prof. Dr Nenad Radović *(Serbia)*
Prof. Dr Nenad Vušović *(Serbia)*
Prof. Dr Nicanor Cimpoesu *(Romania)*
Prof. Dr Nobuyuki Masuda *(*Japan*)*
Prof. Dr Onuralp Yucel *(*Turkey*)*
Prof. Dr Pavel Broz *(*Czech Republic*)*
Prof. Dr Petr Solozhenkin *(*Russia*)*
Prof. Dr Petrica Vizureanu *(Romania)*
Dr Sun Zhongmei *(**China**)*
Prof. Dr Ridvan Yamanoglu *(*Turkey*)*
Prof. Dr Rodoljub Stanojlović *(Serbia)*
Prof. Dr Rositsa Paunova *(**Bulgaria**)*
Prof. Dr Sead Ćatić *(Bosnia* and *Herzegovina)*
Prof. Dr Sergey Krasikov *(*Russia*)*
Dr Slavomír Hredzák *(*Slovakia*)*
Prof. Dr Snežana Milić *(Serbia)*
Prof. Dr Snežana Šerbula *(Serbia)*
Prof. Dr Srba Mladenović *(Serbia)*
Dr Srećko Stopić *(Germany)*
Prof. Dr Stojan Groudev *(Bulgaria)*
Prof. Dr Sulejman Muhamedagić *(Bosnia and Herzegovina)*
Prof. Dr Svetlana Ivanov *(Serbia)*
Prof. Dr Tatjana Volkov-Husović *(Serbia)*
Prof. Dr Tomaš Havlik *(Slovakia)*
Prof. Dr Velimir Radmilović *(Serbia)*
Prof. Dr Velizar Stanković *(Serbia)*
Prof. Dr Vesna Grekulović *(Serbia)*
Dr Vladan Ćosović *(Serbia)*
Vladan Mihailović *(Serbia)*
Dr Vladan Kašić *(Serbia)*
Prof. Dr Vladimir Krstić *(Canada)*
Prof. Dr Vladislav Kecojević *(USA)*
Dr Walter Valery *(Australia)*
Prof. Dr Xuewei Lv *(China)*
Prof. Dr Yong Du *(China)*
Prof. Dr Žarko Radović *(Montenegro)*
Prof. Dr Zdenka Zovko Brodarac *(Croatia)*
Dr Zoran Stevanović *(Serbia)*
Prof. Dr Željko Kamberović *(Serbia)*

ORGANIZING COMMITTEE

Prof. dr Ljubiša Balanović, Full Professor *(UB TF Bor) - president*
Prof. dr Saša Stojadinović, Full Professor *(UB TF Bor) - vice-president*
Prof. dr Srba Mladenović, Full Professor *(UB TF Bor) - vice-president*
Dr Ana Kostov, Principal Research Fellow *(MMI Bor) - vice-president*

Prof. dr Nada Štrbac, *Full Professor (UB TF Bor)*
Prof. dr Dragan Manasijević, *Full Professor (UB TF Bor)*
Prof. dr Vesna Grekulović, *Full Professor (UB TF Bor)*
Prof. dr Đorđe Nikolić, *Full Professor (UB TF Bor)*
Prof. dr Milan Radovanović, *Full Professor (UB TF Bor)*
Prof. dr Marija Petrović Mihajlović, *Full Professor (UB TF Bor)*
Prof. dr Zoran Štirbanović, *Associate Professor (UB TF Bor)*
Prof. dr Milan Gorgievski, *Associate Professor (UB TF Bor)*
Prof. dr Saša Marjanović, *Associate Professor (UB TF Bor)*
Prof. dr Ivana Marković, *Associate Professor (UB TF Bor)*
Prof. dr Žaklina Tasić, *Associate Professor (UB TF Bor)*
Doc. dr Dejan Petrović, *Assistant Professor (UB TF Bor)*
Doc. dr Anđelka Stojanović, *Assistant Professor (UB TF Bor)*
Doc. dr Uroš Stamenković, *Assistant Professor (UB TF Bor)*
Dr Jasmina Petrović, *Assistant with PhD (UB TF Bor)*
Vladimir Nikolić, *Assistant (UB TF Bor)*
Milica Zdravković, *Assistant (UB TF Bor)*
Miljan Marković, *Assistant (UB TF Bor)*
Milijana Mitrović, *Assistant (UB TF Bor)*
Milan Nedeljković, *Assistant (UB TF Bor)*
Avram Kovačević, *Teaching Assistant (UB TF Bor)*
Sandra Vasković, *English Lecturer (UB TF Bor)*
Oliver Marković, *IT service (UB TF Bor)*
Violeta Aleksić, *Liquidator (UB TF Bor)*

PREFACE

On behalf of the Organizing Committee, it is a great honor and pleasure to welcome all esteemed participants of the 54th International October Conference on Mining and Metallurgy (IOC 2023), scheduled to take place at the picturesque Bor Lake, Serbia, from October18th to 21st 2023.

The collaborative efforts of the University of Belgrade, the Technical Faculty in Bor, and the Mining and Metallurgy Institute Bor have meticulously organized this year's IOC. Our focus remains unwavering on showcasing the latest research findings and advancements in geology, mining, metallurgy, materials science, technology, environmental protection, and other engineering disciplines. Our primary objective is to foster a dynamic environment where academics, researchers, and industry professionals can come together to share their knowledge, experiences, and innovative ideas while exploring opportunities for collaborative research endeavors.

Our conference agenda is rich and diverse, encompassing plenary sessions, engaging invited lectures, technical presentations, enlightening oral and poster sessions, informative technical tours, a diverse exhibition, and memorable social gatherings. At the heart of this event lies our strong commitment to sustainable development within the mining and metallurgy sector. We are dedicated to exploring ecologically conscious methodologies, responsible resource extraction practices, and cutting-edge technologies that reduce the industry's environmental impact and enhance the well-being of local communities.

The conference proceedings comprise 129 papers authored by individuals from universities, research institutes, and industries in 22 countries. We are proud to welcome participants from Bosnia and Herzegovina, Bulgaria, Canada, China, Croatia, Germany, Greece, India, Iran, Kazakhstan, Libya, North Macedonia, Montenegro, Morocco, Romania, Russia, Slovakia, South Africa, Spain, Turkey, United States, and, of course, Serbia.

We are excited to host the 8th International Student Conference on Technical Sciences (ISC 2023) as part of IOC 2023. This event offers students from Serbia and the wider region a unique chance to showcase their research and discuss the future of their fields with experts.

We sincerely thank the Ministry of Science, Technological Development, and Innovation of the Republic of Serbia for their generous financial support. In addition, we express our profound gratitude to all our sponsors, exhibitors, and friends of the Conference for their contributions and unwavering support for playing a pivotal role in ensuring the success of IOC 2023.

We would like to express our heartfelt thanks to all authors, committees, reviewers, speakers, and chairpersons for their invaluable contributions in shaping IOC 2023.

We look forward to welcoming you to the 55th International October Conference on Mining and Metallurgy (IOC 2024), which will be held in October 2024.

On behalf of the 54th IOC Organizing Committee,

Prof. dr Ljubiša Balanović

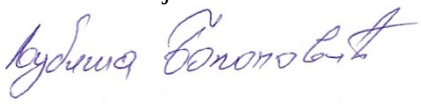

TABLE OF CONTENTS

Plenary Lectures

Invited Lectures

Conference Papers

```
```

A SIMPLE METHOD OF DETERMINING OF BOND WORK INDEX FOR FINER SAMPLES

Vladimir Nikolić, Milan Trumić

Technical Faculty Bor, University of Belgrade, V.J. 12, 19210 Bor, Serbia

Abstract

The Bond's method is based on the experimental determination of the Bond work index which represents a measure of ore resistance to grinding and its denotation is W_i. The conditions for performing the test and initial sample size are precisely defined within Bond's standard test. The procedure for the determination of the Bond work index for finer samples was presented in this paper. These finer samples are usually seen as a problem for practitioners who work on the design and optimization of a plant.

***Keywords**: (Finer Samples, Bond Work Index, Grindability)*

1. INTRODUCTION

The ball mill grindability test sometimes referred to as "the Bond test" was developed in the 1930s by the Allis Chalmers company to help them perform ore hardness characterisation testing to assist in industrial mill sizing [1]. It was extended by Bond (1952) [2] to provide a 'work index' result that was empirically calibrated to make a laboratory work index match the corresponding work index measured in an industrial grinding mill. The fitted equation, in metric form, is given as Equation (1).

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

where in:

P_c - closing screen size (μm),
G - net mass (grams) 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).

The Bond method consists in the experimental determination of the Bond work index, which expresses the resistance of the raw material to comminution and is denoted by W_i. In Bond's standard test, the test performance conditions are precisely defined. The starting size of the sample is also defined. Due to the sheer scope of the test, many researchers have conducted research with the aim of shortening the test and finding alternative methods of determining Bond work index [3-12]. However, very few researchers have dealt with the determination of Bond work index obtained from the test based on finer samples.

Levin (1989) [13] proposed a method for determining the grindability of fine material that included the estimation of energy necessary for the grinding. Magdalinovic et al. (2012) [14] determined the Bond work index on samples of non-standard size. Nikolić and Trumić (2021) [15] provided the procedure for determination of Bond work index for finer samples. This paper represents a continuation of the research published by Nikolić and Trumić (2021) [15].

2. EXPERIMENTAL

The samples used in the study were prepared by crushing in a jaw crusher and then sieved through a sieve with an opening size of -3.35 mm. Two monomineralic types of raw material, zeolite and dacite, were used in the study. Five 10 kg samples with different initial sizes (- 3.35 + 0 mm; - 2.36 + 0 mm; - 1.70 + 0 mm; - 1.18 + 0 mm; - 0.850 + 0 mm) were formed for each individual type of raw material for grinding test based on the standard Bond procedure. The dry grinding was used, simulating a closed grinding cycle, until a circulating load of 250 % was established [17]. A 75 μm closing screen size was used. The Bond work index was calculated by Equation (1).

3. RESULTS AND DISCUSSION

The obtained results for the Bond work index for samples of zeolite and dacite, on fine size classes are shown in Table 1.

Table 1 - Parameters F_{80}, P_{80}, G and value of W_i for samples of zeolite and dacit used on fine material

Sample	Class size (mm)	$P_c = 75\ \mu m$			
		F_{80} (μm)	P_{80} (μm)	G (g/rev)	W_i (kWh/t)
Zeolite	- 3.35 + 0	2440	65.72	2.03	9.834
	- 2.36 + 0	1652	66.40	2.13	10.010
	- 1.70 + 0	1090	66.48	2.20	10.197
	- 1.18 + 0	727	66.84	2.35	10.371
	- 0.850 + 0	544	67.12	2.57	10.572
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

The authors Nikolić and Trumić (2021) [15] provided the equation for the determination of the Bond work index for fine materials, and it is presented by Equation (2). The Equation (2) was tested on a zeolite sample, and further research was conducted on sample dacite.

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

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 - value of coefficient k was given in table 2.

Table 2 - Value of coefficient k

Value of coefficient $\boldsymbol{k}$	$k = 1.47$	$k = 1.48$	$k = 1.49$
BWI (kWh/t)	10 - 17	18 - 20	> 21

The comparative results of the Bond work index for finer materials obtained experimentally by (W_i) and Equation (2) (W_{Fm}), as well as the results found in literature, are shown in Table 3.

Table 3 - Results obtained with experiments and equation (2)

Sample	References	Class size (mm)	F_{80} (μm)	$P_c = 75$ μm			
				W_i (kWh/t)	k	W_{Fm} (kWh/t)	Error Δ (%)
Zeolite	[15]	- 3.35 + 0	2440	9.834	1.47	-	-
		- 2.36 + 0	1652	10.010		9.980	+ 0.30
		- 1.70 + 0	1090	10.197		10.190	+ 0.07
		- 1.18 + 0	727	10.371		10.399	- 0.27
		- 0.850 + 0	544	10.572		10.550	+ 0.21
Dolomite	[14]	- 3.327 + 0	2468	12.70		-	-
		- 2.356 + 0	1662	12.91		12.89	+ 0.15
		- 1.651 + 0	1090	13.16		13.16	0.00
		- 1.168 + 0	727	13.38		13.43	- 0.37
		- 0.833 + 0	544	13.69		13.63	+ 0.44
Commercial aggregate	[17]	- 3.35 + 0	2134	15.0		-	-
		- 2.36 + 0	1492	15.3		15.3	0.00
Copper ore	[14]	- 3.327 + 0	2646	15.67		-	-
		- 2.356 + 0	1729	15.70		15.97	- 1.72
		- 1.651 + 0	1253	15.84		16.24	- 2.53
		- 1.168 + 0	807	16.19		16.54	- 2.16
		- 0.833 + 0	609	16.79		16.84	- 0.30
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
Quartzite	[14]	- 3.327 + 0	2650	22.63	1.49	-	-
		- 2.356 + 0	1790	23.17		23.19	- 0.09
		- 1.651 + 0	1240	23.52		23.62	- 0.43
		- 1.168 + 0	870	24.14		24.04	+ 0.41
		- 0.833 + 0	610	24.72		24.47	+ 1.01

Based on the obtained results presented in Table 3, it can be concluded that when the Bond work index for finer samples is calculated by Equation (2), the reliable results are obtained and the error is not greater than 2.50 %. This fact confirms the accuracy and validity of Equation (2).

4. CONCLUSION

The determination of Bond work index for finer samples is possible if the value of Bond work index for the standard size sample is known and using the Equation (2). This procedure offered the maximum error of -2.53 % for W_i. Such a small error obtained this way confirms the accuracy and validity of the suggested procedure for the determination of Bond work index for finer samples.

ACKNOWLEDGEMENTS

"The research presented in this paper was done with the financial support of the Ministry of Education, Science and Technological Development of the Republic of Serbia, within the funding

of the scientific research work at the University of Belgrade, Technical Faculty in Bor, according to the contract with registration number 451-03-47/2023-01/200131".

REFERENCES

[1] W.L. Maxson, F. Cadena, F.C. Bond, Trans. Metallur. Soc. AIME, 112 (1933) 130-145.
[2] F.C. Bond, Trans AIME, 193 (1952) 484-494.
[3] T.F. Berry, R.W. Bruce, Can. Min. J., 87 (1966) 63-65.
[4] R.W. Smith, K.H. Lee, Trans. Metallur. Soc. AIME, 241 (1968) 91-99.
[5] P.C. Kapur, Trans. Inst. Min. Metallur., 79 (1970) 103-107.
[6] W.E. Horst, J.H. Bassarear, Trans. Metallur. Soc. AIME, 260 (1977) 348-351.
[7] V.K. Karra, CIM Bull., 74 (827) (1981) 195-199.
[8] N. Magdalinović, Int. J. Miner. Process., 27 (1-2) (1989) 125-132.
[9] N. Magdalinović, J. Min. Metallur., 39 (1-4) A (2003) 1-10.
[10] R. Ahmadi, S. Shahsavari, Miner. Eng., 22 (1) (2009) 104-106.
[11] E. Ford, V. Sithole, Copper Cobalt Africa, incorporating the 8th Southern African Base Metals Conference, Livingstone, Zambia, 6-8 July, 2015, 65-68.
[12] D. Todorovic, M. Trumic, Lj. Andric, V. Milosevic, M. Trumic, Physicochem. Probl. Miner. Process., 53 (1) (2017) 321-332.
[13] J. Levin, J. S. Afr. Inst. Min. Metall., 89 (1) (1989) 13-21.
[14] N. Magdalinovic, M. Trumic, G. Trumic, S. Magdalinovic, M. Trumic, Int. J. Miner. Process., 114-117 (2012) 48-50.
[15] V. Nikolić, M. Trumić, Miner. Eng., 165 (2021) 106858.
[16] F.C. Bond, Br. Chem. Eng., 6 (6 and 8) (1961) 378-385 & 543-548.
[17] A. Jankovic, S. Suthers, T. Wills, W. Valery, Miner. Eng., 71 (2015) 133-138.

ISBN-978-86-6305-140-9

IOC M&M 2023

IOC M&M 2023

Proceedings IOC M&M 2023

УНИВЕРЗИТЕТ У БЕОГРАДУ
ТЕХНИЧКИ ФАКУЛТЕТ У БОРУ
1961

INSTITUT