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

54th International October Conference on Mining and Metallurgy

PROCEEDINGS

IOC 2023
International October
Conference

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

trokuttest group

Exhibitions

Labtim

Altium

metalurg

MERIS

1969 FMT ZAJEČAR

REFRATEC

Friends of the Conference

DONAU LAB BEOGRAD

DONCAFÉ

ILR 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
Љубиша Балановић

TABLE OF CONTENTS

Plenary Lectures

Velimir R. Radmilović *(SERBIA)*
Energy: One of the biggest challenges in 21st century 3-3

Jing Yu, Mingshui Luo, Junyi Xiang, Yang You, Zhixiong You, Xuewei Lv *(CHINA)*
Efficient extraction of vanadium from vanadium slag 4-8

Invited Lectures

Batrić Pešić *(UNITED STATES)*
The ongoing restructuring of universities to adopt the sophistication offered by internet 11-19

Yaima Filiberto, Alberto Montenegro, Eugenio Alvarez *(SPAIN)*
Machine learning applied to improving the scrap recycling and melting process in all types of ferrous alloys and steel 20-22

Slobodan Kostić, Qi Fenglai, Savo Pirgić, Nenad Botić, Dobrica Milovanović, Čedomir Sušić, Igor Zlatković *(SERBIA)*
Construction of a new sintering plant 180 m2 within the HBIS Group Serbia Iron & Steel 23-26

Satyananda Patra *(INDIA)*
Acid activation of bentonite: Physico-Chemical characterization and application in goethitic iron ore green pelletization 27-35

Ridvan Yamanoglu *(TURKEY)*
Production of metal-based powders by atomization techniques 36-45

Yong Du, Rainer Schmid-Fetzer, Jincheng Wang, Shuhong Liu, Jianchuan Wang, Qiang Lu, Yuhui Zhang, Kai Li *(CHINA, GERMANY)*
Computational design of engineering materials: case studies for a cemented carbide and a heat resistant Al alloy 46-46

Conference Papers

Ordinartsev Denis, Nadezhda Pechischeva, Svetlana Estemirova, Andrey Rempel *(RUSSIA)*
Cr(VI) photosorption on composite sorbent of montmorillonite with amorphous TiO2 49-52

Mikhail Korovkin, Ludmila Ananyeva, Andrey Zherlitsyn, Sergey Kondratyev, Olesya Savinova *(RUSSIA)*
Electro-pulse crushing in high-purity quartz production 53-55

Žarko Radović, Nebojša Tadić *(MONTENEGRO)*
Analytical simulation of EAF dust enrichment 56-59

Nebojša Tadić, Žarko Radović *(MONTENEGRO)*
Thermal and mechanical relaxation of residual streses in cold rolled aluminium alloy strips *60-63*

Dragan Šabaz, Miloš Stojanović, Dejan Petrović *(SERBIA)*
Selection of anchor type using AHP method *64-67*

Miloš Stojanović, Veljko Lapčević, Ivica Vojinović *(SERBIA)*
Blast fragmentation analysis in Jama Bor by using WipFrag software *68-71*

Veljko Lapčević, Toma Jovičić, Slavko Torbica *(SERBIA)*
Mine ventilation model validation by PQ survey *72-75*

Jelena Đorđević, Jelena Stefanović, Sandra Guševac, Ivan Jelić, Stefan Trujić *(SERBIA)*
Life cycle analysis (LCA) of asphalt layers containing recycled asphalt pavement *76-79*

Jelena Ivaz, Dejan Petrović, Predrag Stolić, Mladen Radovanović, Dragan Zlatanović, Saša Stojadinović, Pavle Stojković *(SERBIA)*
Occupational injuries in underground coal mining: statistical analysis of data *80-83*

Jelena Ivaz, Dejan Petrović, Mladen Radovanović, Dragan Zlatanović, Saša Stojadinović, Pavle Stojković *(SERBIA)*
Prediction of methane emissions in coalmine - Soko *84-87*

C. Prochaska, E. Kokkinos, D. Merachtsaki, A. Lampou, E. Peleka, K. Simeonidis, G. Vourlias, A. Zouboulis *(GREECE)*
Recovery of metallic fractions from medical products labelled for single use *88-91*

Nataša Sarap, Marija Janković, Vojislav Stanić, Ivana Jelić, Marija Šljivić-Ivanović *(SERBIA)*
Analysis of gross alpha and gross beta activity in samples around former uranium mine Gabrovnica *92-95*

Dragan Manasijević, Ljubiša Balanović, Ivana Marković, Uroš Stamenković *(SERBIA)*
Latent heat of some aluminium based phase change alloys for thermal energy storage *96-99*

Anđelka Stojanović, Ivica Nikolić, Isidora Milošević *(SERBIA)*
Position of European countries in sustainable resource management *100-103*

Aleksandar Đorđević, Duško Minić, Milena Zečević, Dragan Manasijević *(SERBIA)*
Mechanical and electrical properties of the ternary Ag-Ge-Sn alloys *104-107*

Milena Zečević, Duško Minić, Aleksandar Đorđević, Dragan Manasijević *(SERBIA)*
Effect of chemical composition on the corrosion resistance of the ternary Ag-Ge-Sn alloys *108-111*

Tatiana Aleksandrova, Nadezhda Nikolaeva *(RUSSIA)*
Extraction of low-dimensional structures of nonferrous and noble metals from refractory raw materials *112-115*

Viša Tasić, Tatjana Apostolovski-Trujić, Bojan Radović, Nevena Ristić, Tamara Urošević, Vladan Kamenović, Zvonko Damnjanović *(SERBIA)*
Air quality measurements in the Bor city during the reconstruction of the copper smelter Bor in 2022 *116-119*

Slavica Miletić, Biserka Trumić, Suzana Stanković *(SERBIA)*
Application of control charts in the laboratory for testing the metallic materials *120-123*

Alexey M. Amdur, Sergei A. Fedorov, Andrey A. Forshev, Nikolay V. Grevtsev, Vera V. Yurak *(RUSSIA)*
Technological aspects of the use of peat as a component of pulverated coal fuel for blast furnaces *124-127*

Ljiljana Avramović, Zoran Stevanović, Vanja Trifunović, Radmila Marković, Dragana Božić, Daniela Urošević, Silvana Dimitrijević *(SERBIA)*
Hydrometallurgical treatment of mining waste from Bor - Serbia in aim of copper recovery *128-131*

Daniel Kržanović, Radmilo Rajković, Ivana Jovanović, Milenko Jovanović, Miomir Mikić *(SERBIA)*
Determination the final contour of the open pit Veliki Krivelj for the mining capacity 23.1 million tons of ore *132-135*

Vladan Marinković, Miroslava Maksimović, Milenko Jovanović, Goran Pačkovski *(SERBIA)*
The use of unmanned aerial vehicles for making the precise 3D topo models and orthophoto images *136-140*

Dejan Tanikić, Anđela Stojić, Jelena Đoković, Miloš Stoljiljković *(SERBIA)*
Mechanical characteristics of the shape memory alloy Cu-Zn-Al *141-144*

Ljiljana Avramović, Vanja Trifunović, Zoran Stevanović, Radmila Marković, Dragana Božić, Dejan Bugarin, Silvana Dimitrijević *(SERBIA)*
Copper recovery from RE-flotation tailings by combined process *145-148*

Milenko Jovanović, Daniel Kržanović, Radmilo Rajković, Vladan Marinković, Miroslava Maksimović, Miomir Mikić *(SERBIA)*
Application of hybrid geogrids in mining *149-153*

Stefan Trujić, Miroslava Maksimović, Vladan Marinković, Ljiljana Avramović, Vanja Trifunović, Dragana Božić *(SERBIA)*
Geological exploration of the technogenic deposit - old flotation tailing pit - Bor with the possibility of leaching *154-157*

Zoran Stevanović, Radmila Marković, Ljiljana Avramović, Vojka Gardić, Jelena Petrović, Dragana Božić *(SERBIA)*
Sustainable and smart mining *158-161*

Snežana Ignjatović, Ivana Vasiljević, Branisav Sretković, Milanka Negovanović *(SERBIA)*
Using gravity data to define structural correlation affecting the formation of Neogene basins *162-165*

Deniz Eylül Akpınar, Batuhan Turgut, Ugur Gurol, Savas Dilibal *(TURKEY)*
Characterization of wire arc additively manufactured wear-resistant bimetallic component *166-169*

Mistreanu Sebastian, Ramona Cimpoeșu, Dragoș Achiței, Mihai Popa, Daniela Lucia Chicet, Vasile Manole, Ana-Maria Scripcariu, Nicanor Cimpoesu *(ROMANIA)*
Sandblasting process influence on stainless steel cutting element properties *170-174*

Đorđe Petrović, Katarina Stanković, Latinka Slavković Beškoski, Ksenija Kumrić *(SERBIA)*
Removal of Cu(II) from aqueous solutions using adsorbent based on chitosan hydrogel beads *175-178*

Jovan P. Šetrajčić, Siniša M. Vučenović *(BOSNIA AND HERZEGOVINA)*
Modified basic properties of electrons in layered nanocrystals with a complex lattice *179-182*

Irena Nikolić, Milena Tadić, Dijana Đurović, Nevena Cupara, Ivana Milašević *(MONTENEGRO)*
Kinetic and thermodynamic aspects of strontium adsorption by steelmaking slag *183-186*

Miomir Mikić, Milenko Jovanović, Sandra Milutonović, Daniel Kržanović, Radmilo Rajković *(SERBIA)*
New flotation plant Veliki Krivelj monitoring plan *187-190*

Miomir Mikić, Radmilo Rajković, Daniel Kržanović, Sandra Milutinović *(SERBIA)*
Recultivation of open pit Veliki Krivelj *191-194*

Farzet Bikić, Khaola Awad, Halim Prcanović, Mirnes Duraković *(BOSNIA AND HERZEGOVINA)*
Analysis of influenced factors on tropospheric ozone content in the city of Zenica during 2020 *195-198*

Sandra Milutinović, Ljubiša Obradović, Daniel Kržanović, Miomir Mikić, Radmilo Rajković *(SERBIA)*
Flotation tail storage methods *199-202*

Sandra Milutinović, Milena Kostović, Ljubiša Obradović, Srđana Magdalinović, Sanja Petrović *(SERBIA)*
Methods of transportation and discharge of tails to flotation tailings pond *203-206*

Uğur Gürol, Ceren Çelik, Müesser Göçmen, Mustafa Koçak *(TURKEY)*
Microstructural and mechanical characterization of armor steel joint welded with sandwich design *207-210*

Branka Pešovski, Milan Radovanović, Vesna Krstić, Danijela Simonović, Silvana Dimitrijević *(SERBIA)*
Electrochemical characteristics of the anodized titanium oxide films in sulfuric acid *211-215*

Duško Đukanović, Nemanja Đokić, Zoran Aksentijević, Daniel Radivojević, Branisal Stakić *(SERBIA)*
Methane as an untapped energy potential of the "Soko" brown coal mine *216-220*

Žaklina Tasić, Marija Petrović Mihajlović, Ana Simonović, Milan Radovanović, Maja Nujkić, Milan Antonijević *(SERBIA)*
Electrochemical methods for the determination of tryptophan and caffeine *221-224*

Isidora Milošević, Anđelka Stojanović, Sanela Arsić, Ivica Nikolić, Ana Rakić *(SERBIA)*
Circular economy in the era of Industry 5.0 *225-228*

Almaida Gigović-Gekić, Elvis Agović, Belma Fakić, Hasan Avdušinović *(BOSNIA AND HERZEGOVINA)*
Effect of delta ferrite on microstructure and hardness welded joints of steel S21800 *229-232*

Radmila Marković, Dragana Bozić, Zoran Stevanović, Tatjana Apostolovski Trujić, Vojka Gardić, Ljiljana Avramović, Vesna Marjanović *(SERBIA)*
Combining neutralization and adsorption methods for metals removal from Saraka stream *233-236*

Ana Petrović, Radmila Marković, Emina Požega *(SERBIA)*
CNTs as potential material for wastewater purification: a review *237-240*

Zdenka Stanojević Šimšić, Ana Kostov, Aleksandra Milosavljević, Slavica Miletić *(SERBIA)*
Experimental investigations of cualag alloys with 70 at%Cu *241-244*

Ana Kostov, Aleksandra Milosavljević, Zdenka Stanojević Šimšić, Ivan Jovanović *(SERBIA)*
Determination of melt properties in Cu-Fe alloys *245-248*

Vladimir Nikolić, Milan Trumić *(SERBIA)*
A simple method of determining of bond work index for finer samples *249-252*

Ivan Jovanović, Novica Staletović *(SERBIA)*
Management of risk assessment in environmental protection in surface copper mine *253-256*

Jovan P. Šetrajčić, Stevo K. Jaćimovski, Siniša M. Vučenović *(BOSNIA AND HERZEGOVINA)*
Possibility of localized electron states appearance in ultrathin layered crystalline structures *257-260*

Jovica Sokolović, Ivana Ilić, Dragiša Stanujkić, Zoran Štirbanović *(SERBIA)*
Application of VIKOR method for comparison of the washability of coals *261-264*

Vladimir Jovanović, Dejan Todorović, Branislav Ivošević, Dragan Radulović, Sonja Milićević, Marija Ercegović, Slavica Mihajlović *(SERBIA)*
The process of obtaining biochar and the development of the products thus obtained *265-269*

Jelena Petrović, Marija Ercegović, Marija Simić, Marija Koprivica, Jelena Dimitrijević, Marija Marković *(SERBIA)*
Mg/Fe-modified hydrochar with promoted adsorption performances *270-273*

Esra Dokumaci Alkan, Nurdan Ari, Murat Alkan *(TURKEY)*
A coating application of IN718 via self-propagating high-temperature synthesis method *274-277*

Murat Alkan, Esra Dokumaci Alkan, Dilan Ugurluer, Aslihan Karakanat *(TURKEY)*
Production of AlCoCrCuXFeNi alloys via self-propagating high-temperature synthesis method *278-281*

Jarmila Trpčevská, Iveta Vasková, Katarína Pauerová, Martina Laubertová, Dušan Oráč *(SLOVAKIA)*
Zinc volatilization in the primary and the secondary zinc production *282-286*

Dragan Ignjatović, Lidija Đurđevac Ignjatović, Vanja Đurđevac, Katarina Milivojević, Ivan Jovanović *(SERBIA)*
Application of the numerical method in the definition of a substrate of circular cross section 287-291

Dragan Ignjatović, Lidija Đurđevac Ignjatović, Vanja Đurđevac, Mlađen Supić, Dušan Tašić *(SERBIA)*
Influence of the subsoil bearing capacity during formation of high landsfills 292-296

Bojana Živković, Jelisaveta Marjanović, Jelena Đokić, Maja Petrović *(SERBIA)*
Soil and rock properties as a basis for the sanitary lanfill settings 297-300

Milan Gorgievski, Miljan Marković, Nada Štrbac, Vesna Grekulović, Kristina Božinović, Milica Zdravković, Marina Marković *(SERBIA)*
Adsorption kinetics for copper ions adsorption onto onion peels 301-304

Saba Nourozi, Fatemeh Pourasgharian, Ahmad Khodadadi Darban *(IRAN)*
Recovery of copper from low-grade copper ore using organic acid 305-308

Maria Krasteva *(BULGARIA)*
Metodology and equipment for researchung corrosion cracking processes in steel 3H14L (BDS 3692-78) 309-312

Jasmina Nešković, Pavle Stjepanović, Nenad Milojković, Dejan Lazić, Klara Konc Janković, Svetlana Polavder, Ivana Jovanović *(SERBIA)*
Testing the Bond work index on limestone from flue gas desulphurization plant in TPP Ugljevik 313-317

Biljana Zlatičanin, Sandra Kovačević *(MONTENEGRO)*
Impact of titanium addition on microstructure and properties of as-cast Al-Cu15 alloys 318-321

Biljana Zlatičanin, Sandra Kovačević *(MONTENEGRO)*
Effect of cooling rate on mechanical properties of binary Al-Cu23 alloys 322-324

Desislav Ivanov, Irena Peytcheva, Marko Holma *(BULGARIA)*
Horizon Europe AGEMERA project - Agile Exploration and Geo-modelling for European Critical Raw Materials: The potential of Assarel porphyry copper deposit for critical raw materials 325-328

Shehret Tilvaldyev, Uzziel Caldiño Herrera, Jose Omar Davalos, Manuel Alejandro Lira Martinez, Marlenne Alejandra Hernandez Lira, Diego Adan Villordo Melendez *(CANADA)*
Problems of anthropogenic pollution of space 329-334

Mohammed Derqaoui, Abdelmoughit Abidi, Abdelrani Yaacoubi, Khalid El Amari, Omar Oabi, Abdelaziz Bacaoui *(MOROCCO)*
Apatite flotation from low-grade sedimentary phosphate ore 335-338

Nadezhda Kazakova, Alexandar Popov, Georgi Chernev *(BULGARIA)*
Influence of the distribution and content of limestone particles on the properties of blended cements 339-342

Daniel Ogochukwu Okanigbe, Shade Rouxzeta Van Der Merwe *(SOUTH AFRICA)*
Rocks of Obafemi Awolowo University and Environ, Nigeria: structural analysis of geological contact *343-347*

Vladan Kašić, Ana Radosavljević Mihajlović, Jovica Stojanović, Slavica Mihajlović, Melina Vukadinović, Nataša Đorđević, Ivana Jelić *(SERBIA)*
Study of thermally treated zeolitic tuffs of Serbia, deposits "Zlatokop" and "Općište"-Beočin *348-352*

Vesna Grekulović, Aleksandra Mitovski, Milica Zdravković, Nada Štrbac, Milan Gorgievski, Milovan Vuković, Miljan Marković *(SERBIA)*
Electrochemical behavior of copper in chloride medium in the presence of nettle extract *353-356*

Marko Pavlović, Marina Dojčinović, Muhamed Harbinja, Atif Hođić, Dragan Radulović, Mirjana Stojanović, Zagorka Aćimović *(SERBIA, BOSNIA AND HERZEGOVINA)*
Effects of the application of pyrophylite in the composition of protective coatings *357-360*

Tamara Ristić, Nenad Milosavljević, Dobrica Milovanović *(SERBIA)*
Measures for the processing of iron with a higher incoming phosphorus content at the steel shop *361-365*

Ivana Mikavica, Dragana Ranđelović, Milena Obradović, Jovica Stojanović, Jelena Mutić *(SERBIA)*
Microplastic textile fibers in urban soils of Serbia *366-369*

Jianbo Zhao, Xinnan Zhao, Donglai Ma, Yang You, Zhixiong You, Xuewei Lv *(CHINA)*
Preparation of ferronickel by semi-molten smelting a mixture of two types of laterite ore *370-374*

Mladen Radovanović, Dejan Petrović, Jelena Ivaz, Dragan Zlatanović *(SERBIA)*
Possibility of copper ores exploitation using in situ leaching method *375-378*

Ivan Jelić, Nikola Lekić, Nikola Stanić, Miomir Mikić *(SERBIA)*
Selection of an optimal route for relocation of the Ćehotina river bed *379-382*

Milica Zdravković, Vesna Grekulović, Bojan Zdravković, Nada Štrbac, Milan Gorgievski, Miljan Marković *(SERBIA)*
Electrochemical behavior of steel in 0.1 mol/dm3 HCl in the presence of potato peel juice *383-386*

Ivana Marković, Dalibor Jović, Uroš Stamenković, Dragan Manasijević, Ljubiša Balanović, Milan Gorgievski *(SERBIA)*
Microstructure and thermal properties of leaded brass after quenching *387-390*

Mehmet Ali Yildiz *(SERBIA)*
Hot strip mill walking beam slab reheating project *391-394*

Peter Polyak *(SERBIA)*
Finishing mill automation upgrade at hot strip mill *395-400*

Branislav Potić, Ana Arifović *(SERBIA)*
The metallurgical testing results of the boron mineralized material from Valjevo-Mionica basin *401-406*

Uroš Stamenković, Ivana Marković, Srba Mladenović, Saša Marjanović, Avram Kovačević, Milijana Mitrović, Filip Basarabić *(SERBIA)*
The influence of quenching media on different properties of C45 carbon steel *407-413*

Yang You, Jiabao Guo, Zhixiong You, Xuewei Lv *(CHINA)*
Investigation of the mixing and granulation behavior of iron ore fines in horizontal high-shear granulator *414-417*

Jovica Sokolović, Grozdanka Bogdanović, Velizar Stanković, Gracijan Strainović, Ivana Ilić, Milan Gorgievski, Miljan Marković *(SERBIA)*
Investigation on beneficiation of iron from copper ore of Mauritania Copper Mine (MCM) by magnetic separation *418-421*

Essen Suleimenov, Rustam Sharipov, Galymzhan Maldybayev, Zhibek Orazaliyeva *(KAZAKHSTAN)*
Investigation of the influence of pulsed electric current on the efficiency of decomposition of aluminate solution *422-423*

Lovro Liverić, Tamara Holjevac Grgurić, Sunčana Smokvina Hanza, Wojciech Sitek, Vedrana Špada, Marko Kršulja *(CROATIA)*
Influence of silver content on martensitic transformation of Cu-Al-Ag alloy *424-427*

Hasan Ali Taner, Vildan Onen *(TURKEY)*
Evaluation of the efficiency of different collectors in the chalcopyrite flotation *428-434*

Vesna Conić, Dragana Božić, Miloš Janošević, Ljiljana Avramović, Vanja Trifunović, Dejan Bugarin, Ivana Jovanović *(SERBIA)*
A pyro-hydrometallurgical process for the recovery of zinc from jarosite waste *435-438*

Maria Krasteva, Rumen Petkov *(BULGARIA)*
Research the rate of chemical corrosion of steel 3X14H2 (BDS 3692-78) *439-442*

Srba Mladenović, Bojan Novaković, Ivana Marković, Uroš Stamenković *(SERBIA)*
Effect of casting speed and water flow on tensile strength, elongation and microstructure of continuous cast copper wire *443-447*

Nadira Bušatlić, Ilhan Bušatlić, Dženana Smajić-Terzić *(BOSNIA AND HERZEGOVINA)*
Dependence of compressive strength of geopolymer based on fly ash and alkaline activator ratio *448-451*

Gergana Meracheva, Efrosima Zaneva-Dobranova, Nikolay Hristov *(BULGARIA)*
Hydrocarbon potential of the Lower Paleozoic sediments in NE Bulgaria by geochemistry and well-logging *452-455*

Dragana Marilović, Grozdanka Bogdanović, Sanja Petrović *(SERBIA)*
Leaching of flotation tailings with a solution of sulfuric acid and ionic liquid *456-459*

Ivana Jovanović, Vesna Conić, Dragan Milanović, Daniel Kržanović, Tanja Stanković, Daniela Urošević, Miloš Janošević *(SERBIA)*
Determination of Bond rod mill work index of a very low-grade copper ore *460-463*

Hasan Ali Taner, Ali Aras, Muhammad Hashim Rasa *(TURKEY)*
Investigation of the effect of depressant and collector conditioning times on cobalt recovery by flotation *464-467*

Aleksandar Cvetković, Žaklina Tasić, Marija Petrović Mihajlović, Maja Nujkić, Milan Radovanović, Ana Simonović *(SERBIA)*
Microplastics *468-471*

Sanja Petrović, Srđana Magdalinović, Ljubiša Obradović, Sandra Milutinović, Bojan Drobnjaković, Slađana Krstić *(SERBIA)*
Tailing management: tailings filtering equipment *472-475*

Jelena Stefanović, Jelena Đorđević, Sandra Guševac *(SERBIA)*
XRD analysis of corrosion product formed in industrial aggressive environment *476-480*

Muhamad Ghulam Isaq Khan, Filip Rajković, Miljana Popović, Dejan Prelević, Aleksandar Ćitić, Tamara Radetić *(SERBIA)*
Initiation of abnormal grain growth in cold-rolled sheet of AA5182 Al-Mg alloy: role of texture *481-484*

Danijela Voza, Hesam Dehghani, Milica Veličković *(SERBIA)*
The dissolved oxygen prediction based on the machine learning techniques *485-488*

Hasan Açan, Hasan Ergin *(TURKEY)*
A novel model for minimizing mine closure costs and the optimum final quarry boundry *489-492*

Ivana Jovanović, Dragan Milanović, Oliver Dimitrijević, Vesna Conić, Igor Svrkota *(SERBIA)*
Role of wing tank in DMS process. Suspension velocity through the seal leg orifice – case study *493-496*

Dejan Petrović, Jelena Ivaz, Saša Stojadinović, Predrag Stolić, Dragan Zlatanović *(SERBIA)*
Risk management and mining machines maintenance – a brief review *497-500*

Stefan Đorđievski, Dragana Adamović *(SERBIA)*
History of surface water pollution by mining and metallurgical activities in Bor, Serbia *501-504*

Olivera Dragutinović, Vaso Manojlović, Đorđe Veljović, Stefan Dikić, Marko Simić *(SERBIA)*
Investigation of the properties of Co-Cr-W and Co-Cr-Mo alloys coated with hydroxyapatite for use in dental implants *505-509*

Zoran Karastojković, Dragoslav Gusković, Ognjen Ristić, Zorica Kovačević *(SERBIA)*
About the "relative plasticity" between steel matrix and non-metallic inclusions *510-513*

Aleksandar Jovanović, Mladen Bugarčić, Milena Milošević, Marija Vuksanović, Muna Abdualatif Abduarahman, Miroslav Sokić, Aleksandar Marinković *(SERBIA, LIBYA)*
Modified hybrid cellulose membrane for Nickel(II) ions removal from industrial wastewater *514-517*

Elena Todorova, Nadezhda Kazakova, Georgi Chernev *(BULGARIA)*
Structural investigation via SEM analysis of silica hybrid materials *518-521*

Tanja Kalinović, Jelena Kalinović, Jelena Milosavljević, Ana Radojević, Snežana Šerbula *(SERBIA)*
Atmosperic bulk deposition as environmental quality indicator *522-526*

Gordana Marković, Vaso Manojlović, Miroslav Sokić, Jovana Ružić, Dušan Milojkov *(SERBIA)*
Designing biocompatible high entropy alloys using Monte Carlo simulations *527-530*

Tatjana Volkov-Husović, Sanja Martinović, Ana Alil, Milica Vlahović *(SERBIA)*
Application of image analysis for cavitation erosion resistance monitoring of some engineering materials *531-534*

Milan Nedeljković, Srba Mladenović, Jasmina Petrović, Milijana Mitrović *(SERBIA)*
Changes in the structure and density of copper during the refining smelting process *535-538*

Jasmina Petrović, Srba Mladenović, Ivana Marković, Milan Nedeljković, Milijana Mitrović *(SERBIA)*
Microstructure analysis of EN AW 6061 alloy using a SEM microscope after artificial aging *539-542*

Milijana Mitrović, Saša Marjanović, Biserka Trumić, Jasmina Petrović, Milan Nedeljković *(SERBIA)*
Effects of cold rolling and annealing processes on the microstructure and properties of micro-alloyed copper *543-546*

Makedonka Dimitrova, Jasminka Dimitrova Kapac *(NORTH MACEDONIA)*
Unlocking energy efficiency: financing preferences for SMEs in the Republic of North Macedonia *547-555*

Zoran Štirbanović, Vesna Vojinović, Jovica Sokolović, Maja Trumić *(SERBIA)*
Analysis of the effectiveness of different methods for cutting samples *556-559*

Ivica Nikolić, Isidola Milošević, Anđelka Stojanović *(SERBIA)*
Land turnover increases due to mining: An empirical analysis of Bor, Serbia, 2013-2022. *560-563*

DONORS *565-590*

AUTHOR INDEX *591-596*

CHANGES IN THE STRUCTURE AND DENSITY OF COPPER DURING THE REFINING SMELTING PROCESS

Milan Nedeljković, Srba Mladenović, Jasmina Petrović, Milijana Mitrović
Technical Faculty Bor, University of Belgrade, V.J. 12, 19210 Bor, Serbia

Abstract
The technology of pyrometallurgical copper production ends with a fire-refining process. This process, as the first stage of refining blister copper, should reduce the impurity content in blister copper to a level that, in accordance with existing standards, allows for the optimal management of electrolytic refining technology. In terms of mechanism and physical-chemical changes, this process is identical to the refining smelting process and it is increasingly being used as a supporting process in a wide range of processing operations. Both processes go through a series of steps that are different in their mechanism and characteristics and must be monitored throughout the entire process. Effective monitoring of these steps enables the installation of the optimal technology for those processes. In this study, changes in density and microstructure that impact the quality of copper during the fire refining and refining smelting processes were observed.

Keywords: *pyrometallurgy, fire-refining, blister copper*

1. INTRODUCTION

Copper, thanks to its properties, is the third most commonly used metal in the world, with a wide range of applications, and demand for it continues to grow. Due to its excellent characteristics, it is used as an alloying element in metallurgy. The processes for obtaining copper can be divided into pyrometallurgical and hydrometallurgical methods. Approximately 90% of copper is obtained through pyrometallurgical processes, while the use of hydrometallurgical methods is limited to copper oxide ores [1].

Copper is required to possess the highest possible electrical conductivity, high plasticity, and, simultaneously, appropriate mechanical properties. The production of copper of this quality is possible by two-stage purification of blister copper. The first phase of purification, known as fire-refining, is important for removing a higher level of impurity constituents from liquid blister copper. The basic impurities present in raw copper are as follows: Fe, Ni, S, O, Pb, Zn, Sn, Bi, As, Sb, Se, Te, Ag, and Au. These impurities, considering their impact on the quality of copper, can be categorized into groups of impurities that significantly affect electrical conductivity, plasticity, mechanical properties, and so on [2]. Blister copper with an average purity of 98.5 - 99% Cu is fire-refined so that the content of impurities in the refined copper is reduced from 0.8 - 2.5% to 0.2 - 0.3%. In this purification stage, nearly all of the contained S, Fe, O, As, Sb, Pb, and Bi are removed [2, 3].

The fire-refining process is applied to both liquid and solid raw copper. Processing liquid charge significantly saves on fuel, shortens the overall operation time, and increases furnace productivity. Through the fire-refining process, the purified copper is cast into anodes, known as anode copper, which is then sent to the electrolytic refining operation [4].

The complete fire-refining process is organized into several phases: the furnace preparation and charging phase, the oxidation phase, the slag removal phase, the reduction (smelting) phase, and the copper casting phase. During each operation, the most sensitive parts of the furnace, casting machine, and other additional equipment deform or are destroyed. For this reason, it is essential to prepare the furnace and other devices before the start of each operation [4, 5].

The density of copper during the refining process varies at different stages. Before oxidation, and especially during the oxidation phase, copper has the lowest density due to the presence of impurities in the liquid copper, which have a lower density than copper itself [6]. By removing these impurities, the density of copper increases, reaching its highest value at the end of the reduction phase. According to studies, the amount of hydrogen, SO_2, and other gases in copper impacts its density. The temperature at which the procedure is performed, more precisely the temperature at which a sample is collected, also affects the density of copper during the process. The density of the sample taken during casting is one of the key indicators of copper quality, and it is used to determine the purity of refined copper [7].

2. EXPERIMENTAL

The practical part of this study was realized with the previous technology of the Smelter in Bor, by taking samples from the anode furnace. In order to become familiar with all aspects of refining technology and to organize the sample collection, the process of the fire-refining activities was tracked before starting the experiment. The collection of the sample during the operation was the first stage of the experiment. A special spoon was used just for collecting samples. In the first series, the furnace operating regime was recorded, and a specific number of samples of liquid copper were collected from each phase. Samples were collected at 30 minute intervals. The final phase of the experiment was analyzing the process by examining changes in copper density and changes in the microstructure of copper.

3. RESULTS AND DISCUSSION

The density of each collected sample was measured to monitor density changes during operations. The determination of density was carried out using a hydrostatic scale. Changes in copper density during the fire-refining process are shown in Figure 1.

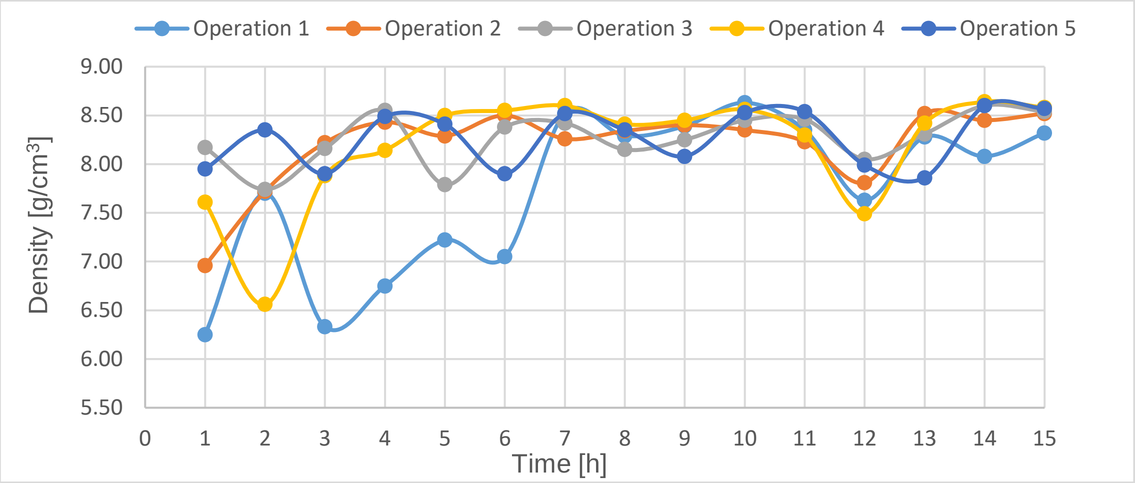
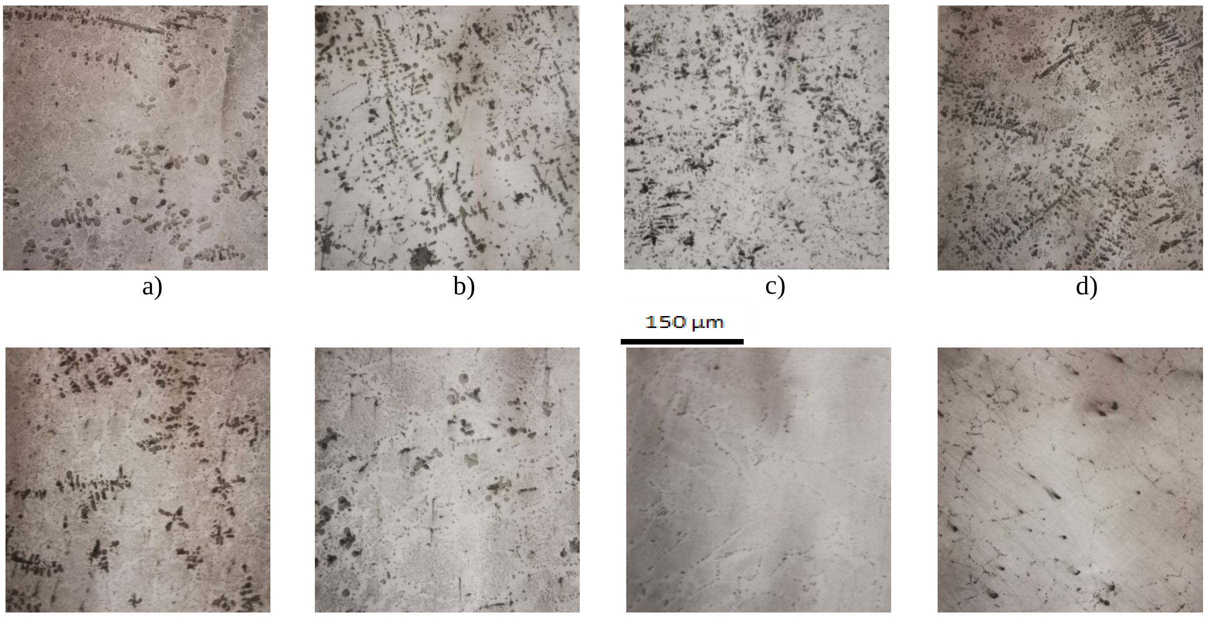


Figure 1 - Change in copper density during fire-refining operations

By analyzing the obtained results, it was determined that the average density of copper consistently rises during the oxidation phase. This increase in density is caused by a reduction in the weight percentage of impurities in the liquid copper system, which has a lower density than copper. In the following stage, which includes the poling and reduction operations, the average density of copper significantly decreases. It's important to mention that the furnace atmosphere also influences on the density of copper samples collected during the fire-refining process.

Studying the changes in microstructure in solidified copper samples obtained during the operations is one way to monitor the fire-refining process. Monitoring was performed by taking samples during the refining operations at specific time intervals, approximately every 25 minutes. The samples were then put through to a complete metallographic study. Microphotographs can be used to determine the oxygen content in the molten metal, specifically the increase or decrease in the oxygen percentage during the refining process. There are numerous methods for determining the amount of Cu_2O or O_2 in copper throughout the refining process. For samples that have a hypoeutectic composition with a lower O_2 content, the percentage of oxygen can be determined by comparing the surface of the samples with the GOST standard at the same magnification (200:1). The microstructure of copper with variable oxygen concentration during the fire-refining process is shown in Figure 2.



a) b) c) d)

e) f) g) h)

Figure 2 - Microstructure of copper with variable oxygen content during the fire-refining process: (a) 0.77% O_2; (b) 0.91% O2; (c) 1.1% O2; (d) 1.34% O2; (e) 0.82% O2; (f) 0.52% O2; (g) 0.39% O2; (h) 0.01% O2

In Figure 2(a), the microstructure of samples from the phase of initial filling of the anode furnace with blister copper is presented. Cu_2O is precipitated in the form of primary dendritic crystals in the eutectic ($Cu + Cu_2O$). Image 2(b) displays the microstructure of a sample taken during the final stage of loading the anode furnace with blister copper. It can be observed that the microstructure has a hupereutectic composition, so in addition to the eutectic ($Cu + Cu_2O$), it also contains primary crystals of Cu_2O, as well as the presence of non-metallic inclusions. The initially formed crystals have a dendritic shape oriented in the direction of cooling. The microstructure of a sample taken during the middle phase of oxidation is presented in Figure 2(c). The amount of primary Cu_2O crystals that have formed in the eutectic is higher than it was in the previous sample. Figure 2(d) shows the sample's microstructure at the end of the oxidation phase. The microstructure of a sample during the slag removal procedure is shown in Figure 2(e). Cu_2O crystals have precipitated in the form of primary crystals within the eutectic ($Cu + Cu_2O$). Figure 2(f) displays the microstructure of copper samples during the reduction phase. The image shows a reduced number of primary Cu_2O crystals precipitated within the eutectic. The microstructure at the end of the reduction phase is shown in Figure 2(g). The percentage of oxygen in copper is very low. The structure of the copper sample at the end of the casting phase is shown in Figure 2(f). From the image, it is evident that the oxygen content in the copper has increased slightly.

Figure 3 shows the change in copper's oxygen content during the fire-refining process. From the image, it can be observed that the oxygen content in copper decreases during the fire-refining process.

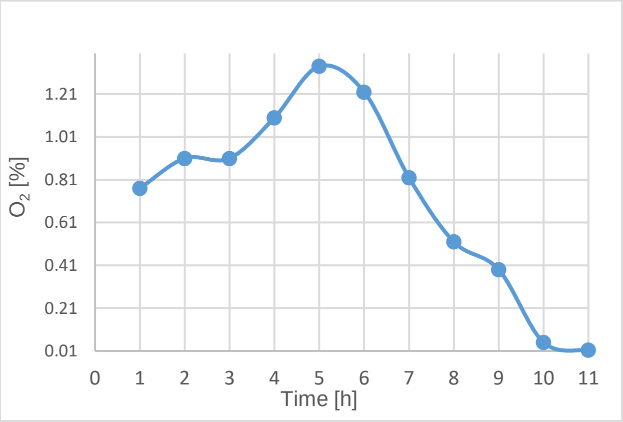


Figure 3 - Change in oxygen content in copper during the fire-refining process

4. CONCLUSION

Through a literature review and based on experimentally obtained results, it is possible to identify the potential for more efficient monitoring of the fire-refining and refining smelting processes. Based on the obtained results, through density measurements and the determination of oxygen content in copper, along with metallographic analysis, it becomes possible to predict and determine the phase of the operation in progress. The density of copper must be understood as a parameter that results from the interplay of various factors crucial for the proper management of the process (temperature, the degree and type of impurities present in copper, oxidation intensity, quality of reducing agents, and so on). The density of the copper samples taken at the end of each observed operation is lower than expected in all cases. Values obtained through such analytical methods must find their place in monitoring the technology of the fire-refining process.

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] J. Davis, *Copper and copper alloys*. ASM International, Ohio, (2001).
[2] D. Gregurek, J. Schmidl, K. Reinharter, V. Reiter, A. Spanring *JOM 70*(11) (2018) 2428-2434.
[3] M. Schlesinger, M. King, K. Sole, W. Davenport, Extractive metallurgy of copper, Fifth edition, Oxford, UK: Perfamon press an imprint of Elsevier Science, 2011.
[4] K. Gargul, S. Malecki, W. Marek, Rudy i Metale Nieżelazne, 58(12) (2013) 843-849
[5] M. Schlesinger, K. Sole, W. Davenport, G. Flores, *Extractive metallurgy of* copper. Elsevier (2021).
[6] J. Oudiz, JOM, 25(12) (1973) 35-38.
[7] P. Goyal, N. Themelis, W. Zanchuk, JOM, 34 (2013) 22-28.

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
BOR