



MINING AND METALLURGY INSTITUTE BOR
TEHNIICAL FACULTY BOR, UNIVERSITY OF BELGRADE



10C 2015
International October
Conference

**47th International October Conference
on Mining and Metallurgy**

PROCEEDINGS

Editors:

Ana Kostov
Milenko Ljubojev

4th – 6th October 2015
Hotel “Jezero” Bor Lake, Serbia



MINING AND METALLURGY INSTITUTE BOR

and



TEHNIICAL FACULTY BOR, UNIVERSITY OF BELGRADE



**47th International October Conference
on Mining and Metallurgy**

PROCEEDINGS

Editors:

**Ana Kostov
Milenko Ljubojev**

4th – 6th October 2015

Hotel “Jezero” Bor Lake, Serbia

47th International October Conference on Mining and Metallurgy

Editors: Ana Kostov, Milenko Ljubojev

Publisher: Mining and Metallurgy Institute Bor

Printed in: "GRAFOMED-TRADE" Bor

**Text printing
preparation:** Vesna Simić

Disclaimer: Authors are responsible for the content, translation and accuracy.

Circulation: 150 copies

CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

622(082)
669(082)

INTERNATIONAL October Conference on Mining and Metallurgy
(47 ; 2015 ; Bor)
Proceedings / 47th International October Conference on Mining and
Metallurgy - IOC 2015, 4th-6th October 2015, Bor Lake, Serbia ;
[organized by] Mining and Metallurgy Institute Bor and Technical
Faculty Bor, University of Belgrade ;
editors Ana Kostov, Milenko Ljubojev. - Bor :
Mining and Metallurgy Institute, 2015
(Bor : Grafomed-trade). - XVI, 535
str. : ilustr. ; 24 cm

Tiraž 150. - Bibliografija uz svaki rad. - Registar.

ISBN 978-86-7827-047-5

a) Рударство - Зборници b) Металургија - Зборници
COBISS.SR-ID 217709324

Bor, October 2015

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



SCIENTIFIC COMMITTEE

47th International October Conference on Mining and Metallurgy

Dr Mile Bugarin (Serbia) - *president*

Dr Ana Kostov (Serbia) - *vice president*

Dr Milenko Ljubojev (Serbia) - *vice president*

Walter Valery (Australia)	Andelka Mihajlov (Serbia)
Boyan Boyanov (Bulgaria)	Biserka Trumić (Serbia)
Stoyan Groudev (Bulgaria)	Branislav Nikolić (Serbia)
Jelena Penavin Škundrić (B&H)	Branka Jordović (Serbia)
Sulejman Muhamedagić (B&H)	Desimir Marković (Serbia)
Mirsada Oruč (B&H)	Dragan Milanović (Serbia)
Fathi Habashi (Canada)	Dragan Milovanović (Serbia)
Vladimir Krstić(Canada)	Dragana Živković (Serbia)
Yong Du (China)	Dragoslav Gusković (Serbia)
Mirko Gojić (Croatia)	Duško Minić (Serbia)
Heikki Jalkanen (Finland)	Endre Romhanji (Serbia)
Jacques Yvon (France)	Jasmina Stevanović (Serbia)
Aleksandar Dimitrov (FYR Macedonia)	Karlo Raić (Serbia)
Carl Heinz Spitzer (Germany)	Lidija Gomidželović (Serbia)
Srećko Stopić (Germany)	Mile Dimitrijević (Serbia)
Costas Matis (Greece)	Mirjana Rajčić Vujasinović (Serbia)
Dimitris Panias (Greece)	Miroslav Sokić (Serbia)
György Kaptay (Hungary)	Nada Štrbac (Serbia)
Iwao Katayama (Japan)	Nadežda Talijan (Serbia)
Kemal Delijić (Montenegro)	Nenad Vušović (Serbia)
Žarko Radović (Montenegro)	Nenad Radović (Serbia)
Krzysztof Fitzner (Poland)	Nedeljko Magdalinović (Serbia)
Luis Filipe Malheiros (Portugal)	Rade Jelenković (Serbia)
Sanda Krausz (Romania)	Radmila Marković (Serbia)
Andrei Rotaru (Romania)	Radoje Pantović (Serbia)
Dimitriu Sorin (Romania)	Rodoljub Stanojlović (Serbia)
Petr M. Solozhenkin (Russia)	Silvana Dimitrijević (Serbia)
Slavomir Hredzak (Slovakia)	Snežana Šerbula (Serbia)
Jakob Lamut (Slovenia)	Svetlana Ivanov (Serbia)
Jožef Medved (Slovenia)	Svetlana Nestorović (Serbia)
Mirjam Jan-Blažič (Slovenia)	Tatjana Volkov-Husović (Serbia)
Seshadri Seetharaman (Sweden)	Zoran Marković (Serbia)
Magnus Ericsson (Sweden)	Zvonko Gulišija (Serbia)
Güven Onal (Turkey)	Vesna Krstić (Serbia)
Onuralp Yücel (Turkey)	Vitomir Milić (Serbia)
Batrić Pešić (USA)	Vladan Čosović (Serbia)
Velimir Radmilović (USA)	Vukoman Jakanović (Serbia)
Vladislav Kecojević (USA)	Željko Kamberović (Serbia)
Aco Janićijević (Serbia)	Živan Živković (Serbia)
Aleksandra Milosavljević (Serbia)	

ORGANIZING COMMITTEE

47th International October Conference on Mining and Metallurgy

Dr Ana Kostov, <i>president</i>	Nevenka Vukašinović
Dr Milenko Ljubojev, <i>vice president</i>	Lidija Đurđevac Ignjatović
Dr Mile Bugarin, <i>vice president</i>	Radiša Todorović
Suzana Cvetković, <i>secretary</i>	Dragan Ignjatović
Aleksandra Milosavljević	Vesna Simić
Lidija Gomidželović	Slavoljub Obradović
Silvana Dimitrijević	Danilo Spalović
Ljubiša Balanović	Saša Stojanov



TABLE OF CONTENTS

PLENARY LECTURES

Essen Suleimenov

PRINCIPLES OF FORMATION OF MICROSTRUCTURE OF MOLTEN SLAG AND
COPPER LOSS ALONG WITH SLAG3

*Daizo Ishiyama, Hiroshi Kawaraya, Hinako Sato, Sachi Wakasa,
Ki-Cheol Shin, Takanori Nakano*

NEW APPROACH OF GEOCHEMICAL MAPS BASED ON
CHEMICAL COMPOSITIONS OF THE RIVER WATER AND SEDIMENTS7

Tsvetina Dobrovol'ska

SELF ORGANIZATION PHENOMENA IN ELECTRODEPOSITED INDIUM ALLOYS11

Alessandro Grazia

ITW WEAR AND ABRASION GROUP15

GEOLOGY

Slavica Mihajlović, Dragan Radulović, Živko Sekulić, Vladimir Jovanović, Vladan Kašić

INFLUENCE OF HIDROPHOBIZED LIMESTONE AS FILLER ON
THE MECHANICAL PROPERTIES OF PVC21

*Miroslava Maksimović, Milenko Jovanović, Sladjana Krstić,
Miomir Mikić, Radmilo Rajković*

SPECIFICS OF CALCULATION THE RESERVES OF
MINERAL RESOURCES IN MATHEMATICAL MODELING25

*Slobodan Radosavljević, Nikola Vuković, Jovica Stojanović,
Ana Radosavljević-Mihajlović, Jovan Kovačević, Rajko Krunić*

CHEMICAL COMPOSITION OF Th-BEARING MONAZITES FROM
THE JURASSIC SEDIMENTS IN THE PLAVNA AREA, SERBIA29

Snežana Dević, Mira Cocić

OPTICAL MICROSCOPY AS A METHOD OF MINERALOGICAL
CHARACTERIZATION THE MATERIALS IN FERROUS METALLURGY33

*Milenko Jovanović, Miroslava Maksimović, Sladjana Krstić,
Miomir Mikić, Daniel Kržanović*

DETERMINATION OF THE QUALITY AND PURPOSE OF BENTONITE
CLAY FROM THE SITE TIJOVAC NEAR SVRLJIG37

Bogoljub Vučković, Slobodan Radosavljević, Miroslav Ignjatović, Veselin Bakić

INVESTMENTS IN GEOLOGY EXPLORATIONS – RESULTS
(REVIEW OF THE KOLUBARA COAL MINES, SERBIA)41

Tatjana Petrović-Cacić, Vladimir Bacanac

GEOLOGICAL 3D MODEL OF THE LIGNITE DEPOSIT
“TAMNAVA-WEST FIELD” (TWF), KOLUBARA COAL MINES (KCM), SERBIA45



<i>Tajana Petrović-Cacić, Radmila Generalović</i> POTENTIAL DOMAINS OF USAGE THE QUARTZ SANDS ON THE LIGNITE DEPOSIT "FIELD E", KOLUBARA COAL MINES (KCM), SERBIA	49
<i>Vladan Kašić, Ana Radosavljević-Mihajlović, Jovica Stojanović, Živko Sekulić, Slavica Mihajlović</i> DEPOSIT OF THE LISINA PHOSPHATES LIKE THE BASE OF RAW MATERIALS FOR PRODUCTION THE NATURAL MINERAL FERTILIZERS	53
<i>Sladana Krstić, Milenko Ljubojev, Dušan Tašić, Vesna Ljubojev</i> MONITORING THE STABILITY OF THE EXISTING COLLECTOR UNDER THE FLOTATION TAILING DUMP VELIKI KRIVELJ (SERBIA)	57
MINING AND MINERAL PROCESSING	
<i>Stefan Djordjević, Jelena Petrović, Vesna Krstić, Radmila Marković, Zoran Stevanović, Vojka Gardić, Marija Milivojević</i> MINERALOGICAL AND CHEMICAL CHARACTERIZATION OF WASTE ROCK SAMPLE FROM THE OVERBURDEN "OŠTRELJSKI PLANIR" BOR	63
<i>Daniel Kržanović, Miomir Mikić, Radmilo Rajković, Nenad Vušović, Milenko Ljubojev</i> LONG-TERM DEVELOPMENT PLANNING OF THE LIMESTONE OPEN PIT "ČOKOČE" WHICH OPERATES WITHIN THE COMPANY HOLCIM SERBIA DOO	67
<i>Živko Sekulić, Slavica Mihajlović, Dragan Radulović, Vladimir Jovanović, Miroslav Sretenović</i> QUALITY AND USE OF MATERIALS BASED ON LIMESTONE „DOBAR KAMEN“ ARANĐELOVAC	73
<i>Ljubiša Andrić, Anja Terzić, Snežana Pašalić, Milan Petrov, Dragan Radulović</i> ACTIVATION OF PHOSPHATES FOR APPLICATION IN COMPOSITE CERAMIC MATERIALS	77
<i>Miomir Mikić, Miroslava Maksimović, Milenko Jovanović, Daniel Kržanović</i> REVIEW OF IMPACT ON THE ENVIRONMENT OF THE OPEN PIT MINE SOUTH MINING DISTRICT - MAJDANPEK	83
<i>Miomir Mikić, Milenko Jovanović, Miroslava Maksimović, Radmilo Rajković</i> REVIEW OF IMPACT ON THE ENVIRONMENT OF THE COAL OPEN PIT – PLJEVLJA, MONTENEGRO	87
<i>Almir Osmanović, Bahrudin Šarić, Ferid Mulahalilović, Fehmo Mrkaljević</i> RECONSTRUCTION AND AUTOMATIZATION THE LUBRICATION SYSTEM OF BUCKET WHEEL EXCAVATOR	91
<i>Aleksandra Stojanović, Milan Trumić, Maja Trumić</i> THE INFLUENCE OF PARTICLE SHAPE ON SCREENING KINETICS	95
<i>Daniela Urošević, Vojka Gardić, Radiša Todorović, Mile Dimitrijević, Dragana Medić, Tamara Urošević, Branko Zečević</i> COPPER REMOVAL FROM IRON ORE USING THE COMBINED PROCEDURE OF SULPHATIZATION ROASTING - WATER LEACHING	101



<i>Sanja Petrović, Mirjana Rajčić-Vujasinović, Milan Čekerevac, Zoran Stević</i> INFLUENCE OF FERRATE(VI) ON ANODIC OXIDATION OF MINERAL COVELLITE IN ALKALINE SOLUTION	105
<i>Zorka Jugović, Danijela Pecarski, Radisav Vulović</i> SIGNIFICANCE AND APPLICATION OF ZEOLITE	109
<i>Blagica Cekova, Viktorija Bezhovska, Filip Jovanovski</i> SYNTHESIS OF ZEOLITE 4A FROM THE NATURAL RAW MATERIAL "PEMZA"	113
<i>Baisui Han, Batnasan Altansukh, Kazutoshi Haga, Zoran Stevanović, Daniela Urošević, Radmila Marković, Ljiljana Avramović, Yasushi Takasaki, Nobuyuki Masuda, Daizo Ishiyama, Atsushi Shibayama</i> COPPER RECOVERY FROM MINE TAILINGS OF THE BOR MINE BY THE BEAKER AND PRESSURE OXIDATION LEACHING	117
<i>Nobuyuki Masuda</i> SUSTAINABLE DEVELOPMENT – EXPERIENCE OF JAPANESE MINING INDUSTRY	123
<i>Dragan Ignjatović, Lidija Djurdjevac Ignjatović, Milenko Ljubojev, Dušan Tašić, Dragan Zlatanović</i> CARRYING CAPACITY OF ANCHORS IN THE ORE BODY “T2”	127
<i>Lidija Đurđevac Ignjatović, Dragan Ignjatović, Milenko Ljubojev, Dušan Tašić, Dragan Zlatanović</i> SPRAYED CONCRETE METHODS AND REASONS FOR CHANGE THE DRY-MIX TO WET-MIX METHOD	131
<i>Rodoljub Stanojlović, Jovica Sokolović, Nikola Čirić</i> MINERALOGICAL ANALYSIS OF THE COPPER ORE FROM THE DEPOSIT “SEVERNI REVIR“ OF COPPER MINE MAJDANPEK	135
<i>Velizar Stanković, Grozdanka Bogdanović, Dejan Antić, Darko Milićević</i> OUT-OF-BALANCE COPPER ORES LEACHING– A CASE STUDY FOR THE ORE DEPOSIT “KRAKU BUGARESKU”	141
<i>Ivana Jovanović, Vladan Milošević, Ljubiša Andrić, Dejan Todorović, Zoran Bartulović</i> DEPENDENCE OF COPPER CONCENTRATE GRADE AND RECOVERY ON GRINDING FINENESS	145
METALLURGY AND MATERIALS SCIENCE	
<i>Srdan D. Matijašević, Snežana R. Grujić, Vladimir D. Živanović, Jelena D. Nikolić, Vladimir S. Topalović, Snežana N. Zildžović, Sonja V. Smiljanić</i> DTA AND IR STUDY OF LITHIUM GERMANATE PHOSPHATE GLASS	151
<i>Zorica Lazarević, Stevan Dimitrijević, Miodrag Mitrić, Silvana Dimitrijević, Milica Petrović, Martina Gilić, Nebojša Romčević</i> RAMAN SPECTROSCOPY STUDY OF ANODIC FILM ON Ag ₄₃ Cu ₃₇ Zn ₂₀ ALLOY	155
<i>Vanya Desimirova Gandova</i> NEW THERMODYNAMIC DESCRIPTION OF SOME SOLID PHASES OF Co–Zn BINARY SYSTEM	159
<i>Vanya Gandova, Kristina Lilova</i> THERMODYNAMIC DESCRIPTION OF LIQUID PHASE IN THE Ni–Sn–Bi TERNARY SYSTEM	163



<i>Sorin Dimitriu, Mircea Dobrescu, Marius Vasilescu</i> THE EFFECT OF NITROGEN, OXYGEN AND CARBON ON THE STRUCTURE AND PROPERTIES OF THE TITANIUM BASED ALLOYS	167
<i>Alexander Peltekov, Katya Dineva, Boyan Boyanov</i> RECYCLING OF ELECTRONIC SCRAP AND OPTIMIZATION OF GOLD RECOVERY	171
<i>Milan Ćekerevac, Ljiljana Nikolić – Bujanović, Ljiljana Karanović, Aleksandar Matković, Mladen Zdravković, Bojana Laban, Milena Tomić</i> ENCAPSULATION OF THE MICRO-SIZED BARIUM FERRATE(VI) CRYSTALLITES IN THE PARAFFIN WAX	175
<i>Ljiljana Nikolić-Bujanović, Milan Ćekerevac, Milena Tomić, Mladen Zdravković</i> CYCLIC VOLTAMMETRIC STUDY OF TRANSPASSIVE DISSOLUTION OF IRON AND ITS ALLOYS IN ALKALINE SOLUTION	179
<i>Žarko Radović, Nebojša Tadić</i> NUMERICAL SIMULATION OF ESR STEEL INGOT COOLING	185
<i>Anja Terzić, Lato Pezo, Zagorka Radojević, Ljubiša Andrić</i> OPTIMIZATION OF AL ₂ O ₃ SYNTHESIS PROCEDURE USED IN THE PRODUCTION OF COMPOSITE CERAMIC MATERIALS	191
<i>Lidija Gomidželović, Emina Požega, Ana Kostov, Dragana Živković, Aleksandra Milosavljević, Radiša Todorović</i> HARDNESS AND ELECTRICAL CONDUCTIVITY OF DIFFERENT COPPER-BASED SHAPE MEMORY ALLOYS	197
<i>Lidija Gomidželović, Dragana Živković, Vladan Ćosović, Ljubiša Balanović, Emina Požega, Dragan Manasijević, Ana Kostov</i> MICROSTRUCTURE AND ELECTRICAL CONDUCTIVITY OF THE Sb-BASED ALLOYS FROM Au-Ga-In-Sb SYSTEM	201
<i>Lidija Gomidželović, Emina Požega, Nikola Vuković, Ana Kostov, Dragana Živković</i> MICROSTRUCTURE OF DIFFERENT MULTICOMPONENT SHAPE MEMORY ALLOYS	205
<i>Lidija Gomidželović, Dragana Živković, Ana Kostov, Ljubiša Balanović, Dragan Manasijević, Emina Požega, Vesna Krstić</i> CALCULATION OF THERMODYNAMIC PROPERTIES OF Cu-In-Sb ALLOYS FROM INDIUM CORNER BY RKM MODEL	209
<i>Bolysbek Utebayev, Maxat Myrzakhanov, Yergali Markayev, Essen Suleimenov</i> THE POSSIBILITY OF DECOMPOSITION OF CARBON OXIDES BY AN ELECTROCHEMICAL METHOD	213
<i>Marai Khalifa, Taha Ased, Abdelarahim Amar</i> ADVANCED AUTOMATED ORBITAL WELDING TECHNIQUE IN THE REAL TIME PROCESS	217
<i>Dana Stanković, Vesna Conić, Zdenka Stanojević Šimšić</i> COMPARATIVE ANALYSIS OF THE TENKA I AND BLAGOJEV KAMEN (BK) POLYMETALLIC CONCENTRATES	221



<i>Duško Minić, Milena Premović, Dragan Manasijević, Dragana Živković, Ljubiša Balanović, Aleksandar Marković, Milica Tomović</i> EXPERIMENTAL INVESTIGATION OF IZOTHERMAL SECTION AT 300°C OF THE TERNARY Bi–In–Ni SYSTEM	227
<i>Milena Premović, Duško Minić, Dragan Manasijević, Dragana Živković, Vladan Čosović, Aleksandar Đorđević, Dušan Milisavljević</i> EXPERIMENTAL INVESTIGATION AND THERMODYNAMIC CALCULATIONS OF THE Bi–In–Ni PHASE DIAGRAM	231
<i>Biserka Trumić, Aleksandra Ivanović, Saša Marjanović</i> THE INTERACTION OF PLATINUM WITH OXYGEN	237
<i>Biserka Trumić, Aleksandra Ivanović, Saša Marjanović, Draško Stanković, Silvana Dimitrijević, Stevan P. Dimitrijević</i> THE INFLUENCE OF RHODIUM CONTENT ON THE MECHANICAL PROPERTIES OF PLATINUM	241
<i>Zoran Karastojković, Mileša Srečković, Zoran Janjušević, Stojan Ostojić</i> OPTICAL PROPERTIES OF GOLD	245
<i>Irena Nikolić, Velimir Radmilović</i> STRENGTH AND SHRINKAGE OF ALKALI ACTIVATED FLY ASH/SLAG BLENDS AT ELEVATED TEMPERATURES	249
<i>Radomir Zejak, Milena Tadić, Dragoljub Blečić, Irena Nikolić</i> HYDROLYTIC STABILITY OF ALKALI ACTIVATED FLY ASH/SLAG BLENDS	253
<i>Nikola Bajić, Slobodan Stojadinović, Jasmina Pekez, Zoran Karastojković, Mihailo Mrdak, Marko Rakin, Darko Veljić</i> TECHNOLOGY DEVELOPMENT FOR PRODUCTION OF TUBULAR COATED HARDFACING ELECTRODES	257
<i>Yongfeng Chang, Kun Zhao, Batrić Pešić</i> SELECTIVE NICKEL LEACHING FROM PRE-REDUCED LIMONITIC LATERITE ORE UNDER MODERATE CONDITIONS	261
<i>Batrić Pešić, Yongfeng Chang, Keshav Pokharel</i> THE EXPERIMENTAL METHOD IMPROVEMENTS TO STUDY CORROSION OF REINFORCEMENT STEEL IN CONCRETE	267
<i>Aleksandra Milosavljević, Ana Kostov, Radiša Todorović</i> THERMODYNAMIC ASSESSMENTS THE Cu–In–Sn SYSTEM BY THE MUGGIANU METHOD	271
<i>Zdenka Stanojević Šimšić, Dragana Živković, Dragan Manasijević, Ana Kostov, Tamara Holjevac Grgurić, Radiša Todorović, Yong Du</i> LIQUIDUS PROJECTION AND INVARIANT REACTIONS IN THE TERNARY Cu–Al–Ag SYSTEM	275
<i>Dušan Milisavljević, Aleksandar Đorđević, Aleksandar Marković, Duško Minić, Milena Premović</i> EXPERIMENTAL INVESTIGATION OF ISOTHERMAL SECTIONS AT 373 K IN TERNARY Bi–Ge–Sb SYSTEM	279



<i>Aleksandar Đorđević, Dušan Milisavljević, Aleksandar Marković, Milena Premović, Duško Minić</i> EXPERIMENTAL INVESTIGATION AND LIQUIDUS PROJECTION OF THE TERNARY Bi–Ge–Sb SYSTEM	285
<i>Vesna Conić, Mirjana Rajčić-Vujasinović, Vesna Grekulović, Vladimir Bežkoski, Vlastimir Trujić</i> BIOLEACHING OF COPPER AND IRON FROM POLYMETALLIC TENKA CONCENTRATE	289
<i>Roman Alexandrovich Pakhomov, Roman Valerevich Starykh</i> SMELTING OF OXIDE NICKEL ORE IN THE BUBBLE FURNACE	295
<i>Irena Spasova, Marina Nicolova, Plamen Georgiev, Stoyan Groudev</i> COMPARATIVE VARIANTS OF JOINT CHEMICAL AND BIOLOGICAL EXTRACTION OF PRECIOUS METALS FROM SULPHIDE CONCENTRATE	299
<i>Aleksandra Ivanović, Biserka Trumić, Svetlana Ivanov, Saša Marjanović, Vesna Marjanović, Branka Petković, Sladana Vušović</i> OPTIMIZATION OF PdNi ₅ WIRE PRODUCTION PROCESS THROUGH RESPONSE SURFACE METHOD INFLUENCE OF PROCESS PARAMETERS OF PRODUCTION OF PdNi ₅ WIRES ON ELONGATION	303
<i>Marina Nicolova, Irena Spasova, Plamen Georgiev, Stoyan Groudev</i> PARTICIPATION OF MICROORGANISMS IN LEACHING THE COPPER MIXED ORE USING THE SULPHURIC ACID	307
<i>Ekaterina Zhilina, Sergey Krasikov, Larisa Vedmid, Svetlana Zhidovinova, Sergey Agafonov</i> PHASE FORMATION DURING THE ZIRCONIUM AND SILICON OXIDES INTERACTION WITH ALUMINUM	311
<i>Sergey Krasikov, Sergey Agafonov, Ekaterina Zhilina, Olga Pichkaleva, Larisa Vedmid, Svetlana Zhidovinova, Artem Ponomarenko, Boris Gelchinski</i> FORMATION OF INTERMETALLIC COMPOUNDS DURING INTERACTION OF TITANIUM, NICKEL, MOLYBDENUM AND ZIRCONIUM OXIDES WITH METAL REDUCTANTS	315
<i>Mladen Mirić, Svetlana Ivanov, Dragoslav Gusković, Miloš Đorđević, Dragan Đorđević</i> THERMOMECHANICAL PROPERTIES OF THE NEW ALLOYS WITHOUT SILVER FOR WHITE GOLD JEWELRY	319
<i>Aleksandra Ivanović, Biserka Trumić, Saša Marjanović, Draško Stanković, Silvana Dimitrijević</i> THE IMPACT OF COLD DEFORMATION AND CHEMICAL ASSAYS ON MECHANICAL AND STRUCTURAL PROPERTIES OF SOME Pd–Au ALLOYS	323
<i>Aleksandra Milosavljević, Ana Kostov, Radiša Todorović</i> ELECTRICAL CONDUCTIVITY CALCULATIONS IN Sn–In–X (X=Ag, Cu) SYSTEM	327
<i>Željko Kamberović, Zoran Anđić, Marija Korać, Milorad Gavrilovski, Aleksandar Mihajlović, Nikola Jovanović, Nataša Gajić</i> SYNTHESIS OF ENVIRONMENTALLY FRIENDLY MULTIPURPOSE METAL SULFIDE TRIBOLOGICAL MATERIALS	331



<i>Vesna Grekulović, Mirjana Rajčić-Vujasinović, Zoran Stević, Sandra Mitrović</i> INFLUENCE OF CYSTEINE ON ELECTROCHEMICAL BEHAVIOUR OF AgCu50 ALLOY	335
<i>Nataša Z. Tomić, Ahmed Ali Algellai, Đorđe Veljović, Bojan Međo, Marko Rakin, Vesna Radojević, Radmila Jančić-Heinemann</i> FINITE ELEMENT MODELING OF ADHESION BEHAVIOR THE POLYMER BLENDS BASED ON THE EVA/PMMA AS A COATING ON OPTICAL FIBERS	339
<i>Tihomir Kovačević, Željko Kamberović, Zoran Anđić, Marija Korać, Aleksandar Vasić</i> SIMULATION AND EXPERIMENTAL VERIFICATION THE TREATMENT OF DISPERSED ZINC AND IRON BEARING MATERIALS USING SOFTWARE PACKAGE FOR THE WAELEZ PROCESS (SPW)	343
<i>Vaso Manojlović, Milorad Gavrilovski, Željko Kamberović, Miroslav Sokić</i> THE APPLICATION OF THERMITE MIXTURES FOR STEEL ALLOYING	347
<i>Srećko Manasijević, Zdenka Zovko Brodarac, Natalija Dolić, Radomir Radiša, Novica Davitkov</i> IDENTIFICATION OF PHASES FORMED IN Al-Si PISTON ALLOYS	351
<i>Zdenka Zovko Brodarac, Mario Targuš, Natalija Dolić, Martina Radoš</i> OPTIMIZATION OF GREY CAST IRON CASTING TECHNOLOGY BY NUMERICAL SIMULATION	355
<i>Ana Kostov</i> THERMODYNAMIC ANALYSIS OF Al-Si BINARY ALLOYS SYSTEM BY THE FACT-SAGE	359
<i>Mirko Gojić, Ladislav Vrsalović, Senka Gudić, Stjepan Kožuh, Ivana Ivanić, Borut Kosec</i> EFFECT OF ELECTROLYTE TEMPERATURE ON CORROSION BEHAVIOUR OF CuAlNi ALLOY IN 0.9% NaCl SOLUTION	363
<i>Ajka Aljilji, Dragana Živković, Nebija Aljilji</i> THE APPLICATION OF DIFFERENT MATERIALS AND SUSTAINABILITY OF OPTIMAL QUALITY OF DRIED PRODUCT	369
TECHNOLOGY AND CHEMISTRY	
<i>Bagdaulet Kenzhaliyev, Ainur Berkinbayeva, Rustam Sharipov, Artem Kolesnikov</i> CHANGE OF PARAMETERS OF AQUEOUS SOLUTIONS IN LEACHING PROCESS OF COMPLEX MATERIALS	375
<i>Silvana Dimitrijević, Maja Milošević, Suzana Veličković, Slađana Alagić, Mirjana Rajčić -Vujasinović, Stevan Dimitrijević, Biserka Trumić</i> MASS SPECTROMETRY FOR STRUCTURAL CHARACTERIZATION OF NON-CYANIDE GOLD COMPLEX	379
<i>Silvana Dimitrijević, Suzana Veličković, Stevan Dimitrijević, Mirjana Rajčić-Vujasinović, Željko Kamberović, Marija Korać, Biserka Trumić</i> LASER DESORPTION IONISATION TIME-OF-FLIGHT MASS SPECTROMETRY OF ANODIC FILM ON Ag43Cu37Zn20 ALLOY	383



<i>Milan B. Radovanović, Žaklina Z. Tasić, Ana T. Simonović, Marija B. Petrović, Snežana M. Milić, Milan M. Antonijević</i> 2-AMINO-5-ETHYL-1,3,4-THIADIAZOLE LIKE BRASS CORROSION INHIBITOR IN 3% NaCl SOLUTION	387
<i>Ghassan S. A. El-Masry, Mustafa El-Musbahi, Benur Mosbah Maatug</i> INCREASE THE EFFICIENCY OF SOLAR DESALINATION UNIT BY THE INCREASE THE CONDENSATION	391
<i>Mustafa El-Musbahi, Ghassan S. A. El-Masry, Benur Mosbah Maatug</i> CORROSION OF ADHESIVE JOINTS	393
<i>Dragana Božić, Nada Štrbac, Milan Gorgievski, Velizar Stanković</i> ADSORPTION OF COPPER AND NICKEL IONS ONTO BEECH SAWDUST AS AN ADSORBENT	397
<i>Dragana Radovanović, Željko Kamberović, Milisav Ranitović, Marija Korać, Milorad Gavrilovski, Aleksandar Mihajlović</i> INTEGRAL TREATMENT OF COPPER SMELTER WASTEWATER BY COPPER MINE OVERBURDEN	401
<i>Vesna Krstić, Ivan Svrkota, Lidija Gomidželović, Biserka Trumić, Marija Milivojević, Tamara Urošević, Stefan Djordjijevski</i> ANALYTICAL MOISTURE OF COAL AND CONTROL CHARTS	405
<i>Biljana Jovanović, Ljubiša Stamenković, Milana Popović, Boban Todorović</i> COPPER RECOVERY FROM ELECTROLYSIS PROCESS EFFLUENT BY ELECTROWINNING (SERBIA)	411
<i>Radmila Marković, Nobuyuki Masuda, Masahiko Bessho, Ljiljana Avramović, Vojka Gardić, Suzana Stanković, Zorica Sovrlić</i> NEUTRALIZATION OF ARTIFICIAL ACID MINE DRAINAGE WITH DIFFERENT Cu, Al AND Fe IONS CONTENT	415
ENVIRONMENTAL PROTECTION	
<i>Vesna M. Marjanović, Aleksandra Ivanović, Vesna Cvetković Stamenković</i> STABILIZATION/SOLIDIFICATION PROCESSES OF WASTE MATERIALS CONTAINING THE HAZARDOUS SUBSTANCES IN THE FUNCTION OF ENVIRONMENTAL PROTECTION	421
<i>Vesna M. Marjanović</i> BINDING AGENTS AND REAGENTS USED IN THE STABILIZATION/SOLIDIFICATION PROCESSES OF WASTE MATERIALS	427
<i>Vojka Gardić, Radmila Marković, Radojka Jonović, Ljubiša Obradović, Jasmina Stevanović, Zoran Stevanović, Ljiljana Avramović</i> SAMPLING AND ANALYSIS PLAN OF SOIL IN THE BOR RIVER COASTAL AREA	435
<i>Viša Tasić, Marija Živković, Ivan Lazović, Dario Brdarić, Krunoslav Capak, Andrea Barišin, Milena Jovašević-Stojanović</i> MEASUREMENT OF GAS POLLUTANTS IN THE SERBIAN AND CROATIAN SCHOOLS	439



<i>Marija Petrović, Tatjana Šoštarić, Mirjana Stojanović, Jelena Milojković, Marija Mihajlović, Jelena Petrović, Marija Stanojević</i> BIOSORPTION OF HEAVY METALS USING THE AGRO WASTE BIOMASS	445
<i>Ljiljana Avramović, Radojka Jonović, Mile Bugarin, Jasmina Stevanović, Vojka Gardić, Radmila Marković, Marko Jonović</i> PHYSICO-CHEMICAL CHARACTERIZATION OF SOIL CONTAMINATED BY MINING WASTE IN THE VALLEY OF THE BOR RIVER	449
<i>Radojka Jonović, Zoran Stevanović, Marko Jonović, Ljiljana Avramović, Renata Kovačević, Jelena Petrović, Jelena Đorđević</i> THE INFLUENCE OF POLLUTED ENVIRONMENTAL OF THE BOR REGION ON THE QUALITY OF PLANTS	455
RELATED FIELDS: MECHANICAL ENGINEERING, CIVIL ENGINEERING, ARCHITECTURE, ELECTRONICS, INFORMATION, MANAGEMENT, ETC.	
<i>Slavica Miletić, Dejan Bogdanović, Jane Paunković, Miladin Djurić</i> RATIONALE FOR THE APPLICATION OF MULTI CRITERIA DECISION MAKING METHODS IN SUSTAINABLE BUSINESS IN SERBIA	461
<i>Branislav Rajković, Zoran Ilić, Daniela Urošević</i> COMPRESSOR STATION FOR FILTRATION FACILITY IN THE MINE “LECE”	465
<i>Viša Tasić, Marijana Pavlov-Kagadejev, Vladimir Despotović, Darko Brodić, Ivan Lazović</i> PROCESS CONTROL SYSTEM IN THE DISTRICT HEATING PLANT IN BOR	469
<i>Branislav Rajković, Zoran Ilić, Daniela Urošević</i> APPLICATION OF SEW WORKBENCH SOFTWARE FOR GEARED MOTOR SELECTION OF BELT CONVEYOR FOR ORE DRIVE	473
<i>Jelena Stanković, Sandra Filipović, Jelena Đorđević</i> HYDROSTATIC LEVELING SYSTEM - GENERAL PRINCIPLES AND SYSTEM MODELING	477
<i>Sandra Filipović, Jelena Stanković, Jelena Đorđević</i> DETERMINATION THE RESIDUAL STRESSES BY THE HOLE-DRILLING STRAIN GAGE METHOD	481
<i>Aleksandra Milosavljević, Predrag Stolić, Danijela Milošević</i> INTERNET OF LABS AS A NEW CONCEPT IN PREDICTION AND VALIDATION OF RESULTS IN LABORATORY INVESTIGATIONS	485
<i>Shehret Tilvaldyeva, Carlos Felipe Ramírez Espinozab, David Atayde Camposc, Pedro Alonso Macías Vázquez</i> ANALYSIS OF THE GLOBAL RENEWABLE ELECTRICITY CAPACITY	489
<i>Shehret Tilvaldyeva, Carlos Felipe Ramírez Espinozab, David Atayde Camposc</i> HEAT INFLUENCES OF MACHINING PROCESSES ON MECHANICAL PROPERTIES OF MATERIALS	493



<i>Slavica Miletić, Miladin Đurić, Dejan Bogdanović, Bojan Đorđević</i> IMPLEMENTATION THE INTEGRATED MANAGEMENT SYSTEM CONFIRMED IN PRACTICE USING THE MCDM METHOD	499
<i>Bashir Younise, Aleksandar Sedmak</i> MICROMECHANICAL STUDY OF DUCTILE FRACTURE INITIATION AND PROPAGATION ON WELDED TENSILE SPECIMEN WITH A SURFACE PRE-CRACK IN HEAT-AFFECTED ZONE (HAZ)	505
<i>Bojan Stojčević, Snežana Urošević, Valentina Velinov, Slavica Miletić</i> UTILIZATION OF HYDRO POWER PLANTS FOR ELECTRICITY GENERATION IN SERBIA	511
<i>Snežana Urošević, Milovan Vuković, Nada Štrbac</i> MANAGEMENT SYSTEM OF HEALTH AND SAFETY AT WORK	515
<i>Milan Živković, Miodrag Žikić, Saša Stojadinović, Stojan Mitrović</i> ANALYSIS THE FEASIBILITY OF APPLICATION THE COMBINED ORE HAULAGE AT THE FUTURE SURFACE MINE KRAKU BUGARESKU CEMENTACIJA-2	519
<i>Marijana Pantović, Zoran Stević, Mirjana Rajčić-Vujasinović, Dejan Antić, Milica Košević, Gavriilo Šekularac, Marko Jonović</i> COMPUTER SYSTEM FOR ELECTROCHEMICAL INVESTIGATIONS OF MATERIALS	523
AUTHOR INDEX	529



ACTIVATION OF PHOSPHATES FOR APPLICATION IN COMPOSITE CERAMIC MATERIALS

Ljubiša Andrić¹, Anja Terzić², Snežana Pašalić³,
Milan Petrov¹, Dragan Radulović¹

¹Institute for Technology of Nuclear and other Raw Mineral Materials, Belgrade, Serbia

²Institute for Material Testing, Belgrade, Serbia

³Serbian Ministry of Education, Science and Technological Development

ABSTRACT

The aim of this investigation was to increase the reactivity of comminuted phosphate ore for application in composite ceramic materials. The vibratory and planetary mills were used as mechanical activators during experimental research. The obtained results highlighted the presence of both amorphous and crystallized forms appearing in the observed phosphate ore mixture due to the specific genetic conditions which rarely occur in deposits. The heterogenic composition of the ore useful phosphoric part gave optimal results during the leaching test. For the first time, the experiments of phosphate mechano-chemical activation from Lisina ore deposit were performed in order to improve its reactivity.

Keywords: planetary mill, vibratory mill, reactivity, crystal structure, apatite.

1 INTRODUCTION

Phosphate minerals from the phosphate ore commonly belong to the apatite group. These minerals represent an important basic material for industry [1]. A large proportion of the global phosphate reserves are sedimentary deposits, and in terms of quality and P₂O₅ content phosphate ore can be divided into three groups: low grade (12–16%), intermediate-grade (17–25%), and high-grade (26–35%) [2]. Constant development in the industry imposes increased demand for phosphates, since it the major resource for production of fertilizers, food preservatives, and important component of artificial bones [3]. From engineering point of view, phosphorus is irreplaceable as additive in anti-corrosion agents, ceramics, water treatment and metallurgy [4-6]. Despite already wide area of engineering branches, where phosphates are applied, demands for the new applications appear daily; therefore the question of improvement the phosphate ore and its minerals as an important industrial component material is imposed. Also, the run-of-mine phosphate ores are mostly of low grade which need processing or upgrading to match the market grade [7]. Beside procedures, such are flotation [8] and magnetic separation [9], the mechanical activation is a process which is often applied in order to improve the characteristics of comminuted ore grain mixtures which are used as a component in design of various composite materials [10]. Activation does not only effect the change of particle size, it is a complex physical-chemical process which brings about the increase of potential energy, chemical activity and reactivity of the system. The increase of the material reactivity can be efficiently used in rationalization of a process and making the basic technologies cheaper. The goal of this study was to instigate the possibilities of mechano-chemical activation of apatite in phosphate ore.

2 EXPERIMENTAL

In the experiment, a planetary mill "Retsch PM4" and a vibratory mill with balls "Siebetechnik TS250" were used. The mechanical activators were operating at constant

speed, and processed material was being lifted and pushed towards the mill walls, and from this position it fall at parabolic path, becoming activated due to collisions with grinding bodies and other particles [11]. The capacity of the mill is (Q – activator capacity, kg/h; G - processed material amount, kg; t is activation time, h):

$$Q = \frac{G}{t} \quad (1)$$

The energy for the mechanical activation is (E - energy, kWh; N - activator engine power, kW, t - activation time, h):

$$E = N \cdot t \quad (2)$$

Specific energy consumption is $e=N/Q$

Quantitative characterization of products was conducted by the Coulter Electronics-Coulter Multisizer. Chemical analysis of the ore sample was performed by the atomic emission spectroscopy technique: PinAAcle 900 Atomic Absorption Spectrometer (Perkin Elmer, USA). Mineralogical changes in samples were analyzed by means of X-ray powder diffraction (XRD). Qualitative mineralogical analysis was performed on the ore samples by means of polarized microscope with passing through light “JENAPOL-U” (Carl Zeiss-Jena).

3 RESULTS AND DISCUSSION

Experimental investigation was performed on phosphate ore from the ore deposit "Lisina" (Sample 1, Sample 2 and Sample 3) in which apatite is the main phosphorus carrier. Physical characterization of the starting raw material was performed using a sample composed of materials collected from three localities with similar characteristics (except for P_2O_5 content). Preparation of the starting sample was conducted according to the standard technological scheme. The obtained specific mass was in interval 2725-2945 kg/dm³, and density was 1565kg/dm³. The results of granulometric and chemical composition of the starting phosphate ore sample are presented in Table1.

Table 1 *Granulometric and chemical composition of the starting phosphate ore sample*

Size class, mm	M, %	R, %	D, %	Oxide	Sample 1	Sample 2	Sample 3
>25.40	27.27	27.57	100.0	SiO ₂	39.82	56.25	48.15
25.40-22.20	7.96	35.23	72.43	Al ₂ O ₃	10.25	7.01	9.05
22.20-19.10	8.25	43.48	64.47	Fe ₂ O ₃	6.02	4.56	3.12
19.10-15.90	10.5	53.98	56.22	TiO ₂	-	0.4	-
15.90-11.10	13.95	67.93	45.72	CaO	15.89	13.95	19.3
11.10-9.52	7.56	75.49	31.77	MgO	-	0.42	-
9.52-7.93	3.71	79.2	24.21	Na ₂ O	4.15	0.38	0.11
7.93-6.35	4.27	83.47	20.5	K ₂ O	6.25	3.62	0.31
6.35-5.00	2.65	86.12	16.23	P ₂ O ₅	13.99	8.75	17.29
5.00-3.15	5.74	91.86	13.58	LOI	2.59	4.02	2.02
3.15-2.00	2.69	94.55	7.84	S	0.71	0.47	0.42
2.00-0.00	5.45	100.0	5.45	Cl ⁻	0.08	<0.01	0.02
Total	100			F ⁻	0.25	0.17	0.21

The crystallinity of activated samples (detected via XRD) was noticeably lower than that of the initial sample which can be attributed to the effect of mechanical activation. Certain changes in the crystal structure appeared within 30 minutes of activation. Comparison of the XRD diffractograms of the sample before activation and after 120 minutes of activation implies that the length of activation influences the crystallinity of the samples, i.e. the level of crystallinity is decreasing with the increasing activation period.

Minerals identified in the investigated phosphate ore samples by polarized microscope accompanied with the microphotography system are: apatite, kolofanite, quartz, carbonate minerals, mica, feldspar, zircon and certain amount of opaque minerals. A quantity of organic matter was also present. Apatite appears in the form of large prismatic crystals which are often cataclased. Kolofanite appears in the form of large ooids and spherulites which appear isotropic under crossed Nicol prism, i.e. amorphous. This mineraloid is probably krypto-crystalic form of apatite. Carbonates appear as fine-crystalline aggregates which form the basic mass of the observed samples. Quartz appears in two forms: as large isometric crystals with rounded edges, and as less abundant built in basic the mass together with carbonates. Other minerals are negligibly abundant. Quantitative mineralogical analysis was obtained using the chemical, microscopic and XRD analyses (Table 2).

Table 2 *Quantitative mineralogical analysis*

Minerals (in %)	Sample 1	Sample 2	Sample 3
Apatite	36.1	24.1	44.6
Quartz	25.3	59.8	30.1
Sercite	11.7	3.5	9.5
Biotiote	15.1	2.2	4.2
Carbonate	9.9	8.6	9.9
Others	1.9	1.8	1.7

Mechanical activation of the starting phosphate raw material, with fraction size 100 % - 2 mm, was conducted by milling in high-energy mills (vibratory and planetary mill). Activation was conducted in time intervals 30 - 240 min. For the activated material obtained after certain milling time (30 and 120 min), the grain-size composition was determined in order to analyze level of grain size reduction achieved during activation, as it is given in Table 3. Level of reduction, i.e. level of diminishing is ratio on the input (X_A) and output (X_B) for properly defined (referent) grain size; for example 95 %, 80 %, 50 %, etc. Level of reduction $r = X_A/X_B$, regardless of value of cumulative oversize and undersize, is obtained as the ratio of abscissa at t D height on a cumulative curve of input (A) and output (B). Abscissa (X_A) has two values (X_{A80}) and (X_{A95}) since it was adopted for the points - 80 % and 95 % on the curve of cumulative undersize of the starting sample prepared for the activation. Abscissa (X_B) is in the function of activation time and mill type. Data from the Table 3 point out that the reduction level of sample

activated in the planetary mill is multiple times higher than the reduction level achieved in the vibratory mill. This leads to a conclusion that sample was unsuitable for micronization, and optimal conditions were achieved only in planetary mill. It is known that compressive forces in planetary mill are 10-100 times higher than forces in the vibratory or ball mill, which is one of the reasons why higher level of micronization was achieved in the planetary mill. Also, prolonged grinding time in the vibratory mill has no effect on the level of reduction.

Table 3 Interpolated data (XB80) and (XB95) for grain size of activated phosphate composition

X _{B80} , mm	X _{B95} , mm	Level of reduction (r)	Vibratory mill		Planetary mill	
			30 min	120 min	30 min	120min
			X _{B80}		(X _{B95})	
0.640	-	-	0.255	0.255		
		r ₈₀	3.095	3.095	-	-
-	0.840					0.09
		r ₉₅	-	-	-	115

Previously prepared samples are submitted to the leaching treatment. In Table 4, the best achieved results are given, obtained by treating the sample in vibratory mill at the coarseness class -0.05+0.00 mm in 2 % solution of citric acid.

Despite the higher level of amorphization achieved in planetary mill, in comparison with the vibratory mill, the experimentally obtained results of leaching of apatite show that the highest solubility of P₂O₅ was achieved after mechanical activation in vibratory mill.

Table 4. Results of leaching of the phosphate raw material, size class -0.05+0.00mm

Solvent	Starting raw material					Vibratory activation				Planetary activation			
	pH	pH	Fe, g/l	P ₂ O ₅ g/l	P ₂ O ₅ %	pH	Fe g/l	P ₂ O ₅ g/l	P ₂ O ₅ %	pH	Fe g/l	P ₂ O ₅ g/l	P ₂ O ₅ %
1*	7.0	7.6	7·10 ⁻⁴	0.043	0.83	8.0	0.013	0.04	0.77	7.5	1.1·10 ⁻³	-	-
2**	2.0	2.3	0.132	1.675	33.9	2.4	0.77	2.19	42.9	2.4	0.087	2.05	40.7
3***	6.6	7.7	0.132	0.025	0.5	8.1	0.450	0.08	1.70	6.7	0.010	0.09	0.19

*distill.water; **2%sol.citric acid; ***2%sol.ammo.acetate

Based on the results of leaching, using dependence between P₂O₅ leachability level and phosphate coarseness, and activation time, it can be seen that: (1) P₂O₅ leachability level for Sample 1 depends on the coarseness of the activated material in the range 16.3-28.2 %; P₂O₅ leachability level for Sample 1 is increasing up to 240 min.



The only exception appears at 180 min, which can be explained by partial agglomeration. (2) P₂O₅ leachability level for Sample 2 depends on the coarseness of the activated material which is confirmed by low level of exhibited coarseness classes – being in range 2.8-3.11 %. (3) P₂O₅ leachability level for Sample 3 sample depends on the coarseness of activated material, varying from 1 to 10.17 %.

4 CONCLUSION

The conclusions that are based on the investigation of the Lisina phosphate ore before and after mechano-chemical activation are listed as follows: 1. From the aspect of the ore reserves, there is important potential in the phosphate ore mass which enables long-termed exploitation; 2. Mineralogical and physico-chemical investigations conducted by XRD and optic-microscopic methods showed that P₂O₅ content significantly varies in the interval 4-19 % in the observed Lisina deposit; 3. Noticed differences in the structure of the apatite mineral (amorphous and crystal structure) have not been significantly modified in the mechanically activated product; 4. Highest level of P₂O₅ solubility was detected in the amorphous apatite (*Panjevica 2*) after mechanical activation in vibratory mill. 5. General conclusion that can be deducted is that results obtained in this investigation showed that there is a possibility of transferring phosphate ore from insoluble into its soluble phase, and that mechano-chemical activation as a means of mineral activating, has visible effect in a variety of phosphate applications.

ACKNOWLEDGEMENTS

This investigation is supported by Serbian Ministry of Education, Science and Technological Development and it is conducted under following Projects: 33007, 34006, 45008 and 172057.

REFERENCES

- [1] A. Abouzeid, A. Negm, D. Elgillani, *Int. J. Miner. Process.*, 90 (2009), 81-89.
- [2] T. Al-Fariss, F. El-Aleem, E. El-Nagdy, *J. King Saud Univer. – Eng. Sci.* 25 (2013) 113-117.
- [3] A. Abouzeid, *Int. J. Miner. Process.*, 85 (2008) 59-65.
- [4] S. Barlow, A. Manning, *British Ceram. Trans.* 3 (199) 122-131 .
- [5] V. Boldyrev, S. Pavlov, E. Goldberg, *Int. J. Miner. Process.* 44–45 (1993), 181-193.
- [6] Y. Chang, J. Yur, H.Chou, H. Chu, *Wear* 260 (11–12) (2006), 1209-1215.
- [7] Y. Chang, Y. Chiou, R. Lee, *Wear* 257 (3–4) (2004) 347-253.
- [8] D. Elgillani, A. Abouzeld, *Int. J. Miner. Process.* 38 (1993), 235-243.



- [9] I. Páez, I., R. Carrodeguas, A., C. Baudín, J. Mech. Behav. Biomed. Mater.30 (2014) 1-15.
- [10] T. Inoue, K. Okaya, Int. J. Miner. Process. 44-45 (1996) 425-432.
- [11] K. Tkacova, H. Heegn, "Energy transfer and conversion during comminution and mechanical activation", Proc. Int. Conf, 7th European Symposium on Comminution, Ljubljana, Yugoslavia, Part. I, 1990, pp. 367-380.