UNIVERSITY OF BELGRADE

TECHNICAL FACULTY BOR

# 52nd International October Conference on Mining and Metallurgy

IOC2021

International October Conference

# PROCEEDINGS

Edited by

**Saša Stojadinović**

and

**Dejan Petrović**

November 29th – 30th 2021

Bor, Serbia

UNIVERSITY OF BELGRADE
TECHNICAL FACULTY IN BOR

# 52nd International October Conference on Mining and Metallurgy

# PROCEEDINGS

Edited by
Saša Stojadinović
and
Dejan Petrović

November 29th – 30th 2021

Bor, Serbia

**52nd International October Conference**

**on Mining and Metallurgy, IOC 2021**

PUBLISHER:
UNIVERSITY OF BELGRADE - TECHNICAL FACULTY IN BOR, BOR, NOVEMBER 2021

FOR THE PUBLISHER:
DEAN: Prof. dr Nada Štrbac

EDITORS:
Prof. dr Saša Stojadinović
Doc. dr Dejan Petrović

TECHNICAL EDITOR
Pavle Stojković, MSc.

PRINTED BY:
»Štamparija Atlantis d.o.o.« Niš

CIRCULATION: 100 Copies

CIP – Каталогизација у публикацији –

Народна библиотека Србије, Београд

622(082)
669(082)

**INTERNATIONAL October Conference on Mining and Metallurgy (52 ; 2021 ; Bor)**
Proceedings / 52nd International October Conference on Mining and Metallurgy - IOC 2021, November 29th - 30th 2021 Bor, Serbia ; [organizer] University of Belgrade, Technical Faculty in Bor ; [co-organizer Institute for Mining and Metallurgy Bor] ; edited by Saša Stojadinović and Dejan Petrović. - Bor : University of Belgrade, Technical Faculty, 2021 (Niš : Atlantis). - V, 228 str. : ilustr. ; 25 cm

Tiraž 100. - Bibliografija uz svaki rad.

ISBN 978-86-6305-119-5

а) Рударство -- Зборници б) Металургија -- Зборници

COBISS.SR-ID 52072201

## ORGANIZER:

**UNIVERSITY OF BELGRADE – TECHNICAL FACULTY IN BOR**

## Co-ORGANIZER:

**INSTITUTE FOR MINING AND METALLURGY BOR**

## Under the Auspice of:

## The Ministry of Education, Science and Technological Development of the Republic of Serbia

## CONFERENCE SPONSORS

Dundee PRECIOUS METALS

TEHPRO

MUNDORO

RioTinto

## COMMITTEES

## 52nd International October Conference on Mining and Metallurgy, IOC 2021

### SCIENTIFIC COMMITTEE

## ORGANIZING COMMITTEE

# TABLE OF CONTENTS

Aleksandra Milosavljević

**THE COMPLEXITY OF SEM-EDS – WHAT AFFECTS THE QUALITY OF OBTAINED RESULTS?** **1**

Zoran Karastojković, R Perić, M Srećković

**LASER QUENCHING OF CUTTING TOOL STEELS - A REVIEW** **5**

Slavica Miletić, D Bogdanović, E Požega

**IMPACT OF EXTRAORDINARY SECURITY MEASURES TO EMPLOYEES DURING THE PANDEMIC COVID-9** **15**

Daniela Grigorova, R Paunova

**KINETIC STUDY OF SOLID-PHASE REDUCTION OF POLYGRADIENT IRON-CONTAINING MATERIAL** **19**

Emina Požega, D Simonović, S Marjanović, M Jovanović, L Gomidželović, M Mitrović, Z Stanojević Šimšić

**PART I: WHAT MAKES A GOOD THERMOELECTRIC** **23**

Emina Požega, D Simonović, S Marjanović, M Jovanović, L Gomidželović, M Mitrović, S Miletić

**PART II: WHAT MAKES A GOOD THERMOELECTRIC** **27**

Dragan Manasijević, Lj Balanović, I Marković, M Gorgievski, U Stamenković, K Božinović, D Minić, M Premović

**STUDY OF MICROSTRUCTURE AND THERMAL CONDUCTIVITY OF THE Ag–Bi–Sn ALLOYS** **31**

Vladimir S. Topalović, S Matijašević, S Grujić, J Stojanović, J Nikolić, V Savić, S Zildžović

**THE INFLUENCE OF THE PARTICLE SIZE ON CRYSTALLIZATION OF GLASS POWDERS FROM THE SYSTEM $Li_2O$-$Al_2O_3$-$GeO_2$-$P_2O_5$** **35**

Vesna Marjanović, R Marković, V Krstić

**TECHNOLOGIES FOR PHYSICAL TREATMENT OF WATER CONTAINING SELENIUM: A REVIEW** **39**

Vesna Marjanović, R Marković, V Krstić

**TECHNOLOGIES FOR BIOLOGICAL TREATMENT OF WATER CONTAINING SELENIUM: A REVIEW** **43**

Milenko Jovanović, M Mikić, M Maksimović, D Kržanović, R Rajković, E Požega

**USAGE SPECIFICS OF GEOGRIDS** **47**

Srećko Manasijević, Z Zovko Brodarac, N Dolić, M Djurdjević, R Radiša

**INTERMETALLIC BONDING BETWEEN A RING CARRIER AND AN ALUMINUM PISTON ALLOY** 51

Snežana Šarboh

**PATENTED INVENTIONS OF LJUBOMIR KLERIĆ** 55

Miomir Mikic, M Jovanović, R Rajković, D Kržanović, E Požega

**DEGRADED AREA OF VELIKI KRIVELJ QUARRY RECULTIVATION** 59

Dragana Adamović, D Ishiyama, H Kawaraya, O Yasumasa

**EFFECTS OF TAILINGS ON GROUNDWATER ALONG BOR AND BELA RIVERS IN THE BOR MINING AREA, EASTERN SERBIA** 63

Ana Kostov, Z Stanojević Šimšić, A Milosavljević,

**CHARACTERIZATION OF ALLOYS CuAlAu0.5** 67

Marija Milenković, V Jovanović, J Paunković, V Krstić

**MULTICRITERIA ANALYSIS OF THE LEVEL OF SUSTAINABLE DEVELOPMENT OF THE TOPLICA DISTRICT USING THE ELECTRE METHOD** 71

Daniel Kržanović, R Rajković, D Stevanović, M Mikić, M Jovanović, S Petrović

**LONG-TERM PLANNING OF MINING THE LEAD AND ZINC ORE DEPOSIT IN THE BRSKOVO ORE FIELD, THE REPUBLIC OF MONTENEGRO** 75

Radmilo Rajković, D Kržanović, M Mikić, M Jovanović

**CALCULATION OF SAFETY DISTANCE FOR THE OPERATION OF MINING EQUIPMENT IN THE WORKING ENVIRONMENT WITH WEAKENED CHARACTERISTICS AT THE OPEN PIT "NORTH MINING DISTRICT" OF THE COPPER MINE MAJDANPEK** 79

Zdenka Stanojević Šimšić, A Kostov, A Milosavljević, E Požega

**HARDENSS, MICROHARDNESS AND ELECTROCONDUCTIVITY OF ALLOYS WITH VARIABLE Cu CONTENT IN Cu-Al-Ag SYSTEM** 83

Miodrag Banješević

**STRATIGRAPHY AND AGE OF ROCK UNITS AND MINERALIZATION IN THE TIMOK MAGMATIC COMPLEX ANDTHE BOR METALLOGENIC ZONE – A REVIEW** 87

Milan Radivojević, Z Stević, M Tanasković

**DUALPHASED FOURWAYINTERSECTION REGULATED BY TRAFFIC LIGHTS WITH FIXED AND ADAPTIVE MOD OF OPERATION** 93

Filip Gramić, N Rančić, S Filipović, J Đorđević

**USE OF COPPER TAILING AND COPPER SLAG IN D PRINTED CONCRETE PROCESSES** 97

Filip Gramić, N Rančić, S Filipović, J Đorđević,

**POSSIBILITY OF USING MINING WASTE IN THE PRODUCTION OF BRICK PRODUCTS** 101

Stepan O. Vydysh

**GOLD-SILVER ALLOYS ANODIC DISSOLUTION RESEARCH IN HYDROCHLORIC ACID ELECTROLYTES** **105**

Milan Gorgievski, M Marković, D Božić, Vr Stanković, N Štrbac, V Grekulović, M Zdravković

**ADSORPTION ISOTHERMS FOR COPPER IONS ADSORPTION ONTO WALNUT SHELLS** **109**

Miljan Marković, M Gorgievski, N Štrbac, V Grekulović, A Mitovski, K Božinović, M Zdravković

**pH AND CONDUCTIVITYCHANGE DURING THE RINSING AND ADSORPTION OF COPPER IONS ONTO WALNUT SHELLS** **113**

Vesna Grekulović, A Mitovski, M RajčićVujasinović, N Štrbac, M Zdravković, M Gorgievski, M Marković

**ELECTROCHEMICAL BEHAVIOR OF COPPER IN CHLORIDE MEDIUMIN THE PRESENCE OF WALNUT SHELL MACERATE** **117**

Marija Šljivić-Ivanović, S Dimović, I Jelić,

**EXPERIMENTAL DESIGN APPROACH IN RADIONUCLIDE SORPTION** **121**

Ivana Jelić, A Savić, M Šljivić-Ivanović, S Dimović

**INFLUENCE OF SILICA FUME ON SCC CONCRETE PROPERTIES** **125**

Milan Radovanović, A Simonović, M Petrović Mihajlović, Ž Tasić, V Nedelkovski, M Antonijević

**L-LYSINE AS CORROSION INHIBITOR OF STAINLESS STEEL IN RINGER'S SOLUTION** **129**

Dragana Marilović, M Trumić, M Trumić,Lj Andrić

**THE INFLUENCE OF CALCIUM IONS ON DEINKING FLOTATION RECOVERY UNDER DIFERENT CONDITIONS** **133**

Dragana Medić, S Milić, S Alagić, M Nujkić, S Đorđievski, A Papludis

**OPTIMIZATION OF CATHODIC MATERIAL LEACHING PROCESS IN ACID-SULPHATE SOLUTION** **137**

Milijana Mitrović, D Gusković, S Marjanović, BTrumić, E Požega, U Stamenković, J Petrović

**OBTAINING MULTILAYER COPPER STRIPS BY ARB (ACCUMULATIVE ROLL BONDING) ROLLING PROCESS** **141**

Nataša Đorđević, S Mihajlović, N Obradović, A Peleš, S Filipović

**THE INFLUENCE OF HIGH COMPACTION PRESSURE ON CORDIERITE-BASED CERAMICS** **145**

Nataša Đorđević, S Mihajlović, M Sokić, B Marković

**SEM AND X-RAY ANALYSES OF SINTERED MgO / $Bi_2O_3$ BINARY SYSTEM** **149**

Ivana Ilić, J Sokolović, M Trumić, Z Stirbanović

**COMPARATIVE RESULTS OF COPPER FLOTATION FROM SLAG BEFORE AND AFTER THE PROCESS OF MAGNETIC CONCENTRATION** **153**

Daniela Grigorova

**FERROSILICON OBTAINING USING IRON-SILICATE –FAYALITE** **157**

Slavica Mihajlović, M Jovanović, N Đorđević, A Patarić, M Vlahović, V Kašić

**THE CLAY PRELIMINARY TESTING FROM MUNICIPALITY AREA OF REKOVAC** **161**

Milan Milosavljević, M Premović', D Minić, Dn Mansijević, Ar Đorđević, M Kolarević

**EXPERIMENTAL AND THERMODYNAMIC STUDY OF ISOTHERMAL SECTIONS AT 600 °C AND 400 °C OF TERNARY Bi-Cu-Ge SYSTEM** **165**

Aleksandar Đorđević, D Minić, M Premović', D Mansijević, M Milosavljević, V Ristić

**STUDY OF TEMPERATURE PHASE TRANSFORMATION OF THETERNARY Bi-Cu-Ge SYSTEM** **169**

Aleksandar Savić, I Jelić, M Šljivić-Ivanović, S Dimović, N Pudar, A Pfandler

**RECYCLED COARSE AGGREGATE AND FLY ASH EFFECT ON COMPRESSIVE STRENGTH OF SELF-COMPACTING CONCRETE** **173**

Vladan Kašić, D Životić, V Simić, A Radosavljević-Mihajlović, J Stojanović, S Mihajlović, M Vukadinović

**FORECAST RESOURCES OF ZEOLITHIC TUFFS OF SERBIA** **177**

Vladan Kašić, A Radosavljević-Mihajlović, S Radosavljević, J Stojanović, S Mihajlović, M Vukadinović

**GEOLOGICAL AND MINERAL CHARACTERISTICS OF ZEOLITHIC TUFF TOPONICA DEPOSITS NEAR KOSOVSKA KAMENICA** **181**

Konstantin Petkov, V Stefanova, P Iliev

**METHOD FOR UTILIZATION OF THE SULFURIC ACID OBTAINED DURING AUTOCLAVE DISSOLUTION OF PYRITE CONCENTRATE** **185**

Stefan Đorđievski, D Ishiyama, Y Ogawa, Z Stevanović, O Osenyeng, D Adamović, V Trifunović

**MONITORING OF pH VALUE AND CONCENTRATION OF COPPERIN RIVERSDOWNSTREAM FROM BOR MINE IN PERIOD 2015-2021** **189**

VišaTasić, M Cocić, B Radović, T Apostolovski-Trujić

**CHEMICAL COMPOSITION OFPARTICULATE MATTER IN THE INDOOR AIRAT THE TECHNICAL FACULTY IN BOR (SERBIA)** **193**

Snežana Ignjatović, I Vasiljević, M Negovanović

**DEFINING STRUCTURAL CORRELATION USING OF TOTALHORIZONTAL GRADIENT** **197**

Velizar Stanković, M Janošević

**INCREASING THE CAPACITY OF THE COPPER SMELTING COMPANY IN THE COMPANY "SERBIA ZIJIN COPPER" - CHALLENGES AND CONSEQUENCES TO THE ENVIRONMENT** **201**

Vladimir Jovanović, D Todorović, B Ivošević, D Radulović, S Milićević, D Nišić

**CHARACTERIZATION OF PELLET SAMPLES OBTAINED BY PELETIZATION OF LIMESTONE AND SEAWEED** **205**

Vanja Trifunović, L Avramović, R Jonović, S Milić, S Đorđievski, M Jonović

**HYDROMETALLURGICAL TREATMENT OF ELECTIRIC ARC FURNACE DUST IN AIM OF ZINC SEPARATION** **209**

Jovana Bošnjaković, N Knežević, N Čutović, M Bugarčić, A Jovanović, Z Veličković, S Manasijević

**EVALUATION OF ADSORPTION PERFORMANCE OF PHOSPHATES REMOVAL USING CELL-MG HYBRID ADSORBENT** **213**

Dragan Radulović, Lj Andrić, D Božović, V Jovanović, B Ivošević, D Todorović,

**POSSIBILITY OF USING LIMESTONE FROM "PJEŠIVAČKI DO"-DANILOVGRAD DEPOSIT AS FILLER IN VARIOUS INDUSTRY BRANCHES** **217**

Predrag Stolić, J Ivaz, D Petrović, Zoran Stević

**ADVANTAGES OF MINING ENGINEERING CURRICULUM REALIZATION USING SOLUTIONS BASED ON FREE SOFTWARE** **221**

Slađana Krstić, E Požega, S Petrović, S Magdalinović, D Urošević, S Miletić, Z Stojanović Šimšić

**QUALITY INVESTIGATION OF SAND FOR THE PRODUCTION OF AGGREGATES ON VINOGRADI LOCALITY (DELIBLATSKA PEŠČARA)** **225**

Saša Marjanović, D Gusković, M Mitrović, E Požega ,B Trumić, U Stamenković

**INFLUENCE OF COLD ROLLING AND ANNEALING ON HARDNESS OF BIMETALLIC STRIP Cu– Al** **229**

# OBTAINING MULTILAYER COPPER STRIPS BY ARB (ACCUMULATIVE ROLL BONDING) ROLLING PROCESS

**Milijana Mitrović[1], Dragoslav Gusković[1], Saša Marjanović[1], BiserkaTrumić[2], Emina Požega[2], UrošStamenković[1],Jasmina Petrović[1]**

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

[2]Mining and Metallurgy Institute Bor, Zelenibulevar 35, 19210 Bor, Serbia

**Abstract**

*In this paper, the production of multilayer samples, by joining copper strips, by the rolling process at temperatures below the recrystallization temperature is presented.The newly obtained multilayer samples were then subjected to tensile testing and hardness measurement in order to determine their properties.The obtained results show that with increasing degree of reduction, the tensile strength and hardness of the samples increase.Up to the degree of reduction of 66.5%, the tensile strength and hardness of the samples increase slightly, while at a higher degree of reduction of 66.5%, the growth is much more pronounced.*

***Keywords:****Multilayer copper strips, ARB Roll Bonding, hardness, tensile strength.*

## 1. INTRODUCTION

The initial idea for this work was based on the knowledge about the application of ARB (Accumulative Roll Bonding) method for rolling sheets and strips (Figure 1) [1].This method achieves the required metal reduction with minimal stresses, by cutting the rolled sheets, joining and re-rolling, whereby this procedure can be repeated an unlimited number of times [2].There is a joining of metals by hot and cold rolling.Making the joint by hot rolling is a more efficient and widely used production method of rolled multilayer semi-finished products.The joint is made by hot rolling from pre-prepared strips packed and joined, and then heated to the temperature required for hot rolling.The application of hot rolling has its basic meaning in the setting to obtain products of smaller thickness than the initial large pieces without intermediate annealing and to facilitate joining, and the joint is achieved at a lower degree of deformation.Cold rolling technology, especially strips rolling, has a disadvantage in terms of the use of expensive equipment for both preparation and rolling.The requirements for large reduction in one pass impose the use of specialized rolling machines with large roller diameters, small rolling width and low rolling speed, as well as a preparation line within the rolling machine.In addition, solving the disadvantages of hot and cold rolling is done by combining procedures, in such a way that the joining is done by some other process, such as explosive joining, and by further hot or cold rolling pieces of the final dimensions are produced[3,4].

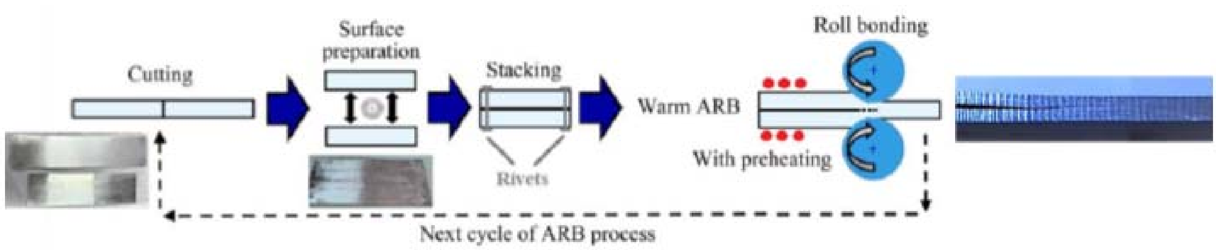


Figure 1. Schematic view of ARB (Accumulative Roll Bonding) rolling process

## 2. EXPERIMENTAL

As a starting material, dip-forming wire in the form of a strip with dimensions 100 x 7 x 1 mm was used, which was rolled on a quarto rolling machine with smooth rollers, diameter D =180 mm.

Rolling was done by cutting 200 strips 100 mm long, 7 mm wide and 1 mm thick.For degreasing, they were boiled in detergent for about 30 minutes, and then washed with a solution of nitric acid (1: 1 solution), distilled water and finally alcohol.After drying, two strips were joined together, whereby the joining was done by placing copper foil on the ends of the sample. Thus, two-layer samples (2 mm thick) were formed, ready for annealing.The samples were annealed at 400 ° C for 10 minutes to reduce the oxidation level of the sample surface.Annealing was performed by inserting the samples into a metal box filled with charcoal.After annealing, rolling was started on a quarto-rolling machine, whereby the obtained samples had a degree of reduction of $\varepsilon_1$ = 40%.Such samples were immediately deposited in a charcoal box, annealed at 400 ° C for about 10 minutes and re-rolled, with a reduction degree of $\varepsilon_2$ = 44.1%.The obtained sample consisted of two layers with a total reduction of $\varepsilon_{uk}$ = 66.5%.After that, two two-layer samples were joined, of course, before their joining, the sample was washed and cleaned again, in order to remove impurities.Joining of these samples was done with copper foil at the ends of the sample. The samples were then annealed for 10 minutes at 400 ° C and then rolled. The degree of reduction after rolling is $\varepsilon_3$ = 48.5%.The obtained samples had four layers.The obtained samples were washed again for degreasing and cleaning, joined in pairs, annealed and rolled, however the process of joining these samples and obtaining eight layers in the sample was not successful.As a final result, a sample with four layers was obtained. The total degree of reduction in relation to the initial sample is $\varepsilon_{uk}$ = 83%.The flow of the whole experiment is schematically shown in Figure 2.

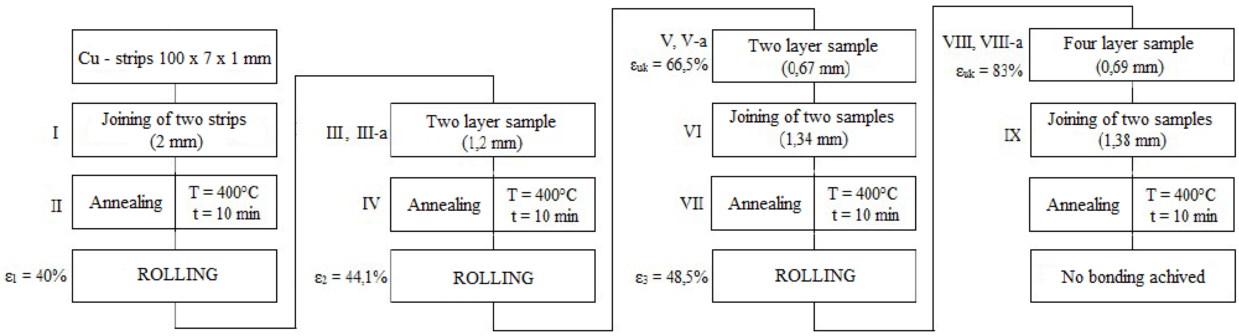


Figure2. Schematic view of the experiment flow

## 3. RESULTS AND DISCUSSION

Visual inspection of the samples has shown that quality bimetallic strips of small thickness below 0.7 mm can be obtained by rolling.

Flaking was not observed in any of the examined samples. The strips have smooth surfaces, even widths along the length, even thicknesses along the length, and the edges are smooth without cracks.

The results of the change in tensile strength and hardness of the samples depending on the degree of reduction are presented in Table 1 and Figures 3 and 4.

Table 1. Hardness and tensile strength values depending on the degree of reduction

| Sample | Degree of reduction ε (%) | Medium hardness value (HV) | Tensile strength $R_m$ ($N/mm^2$) |
|---|---|---|---|
| III | 40 | 103 | 46,221 |
| III - a | 40 | 102 | 44,345 |
| V | 66,5 | 109 | 55,336 |
| V - a | 66,5 | 108 | 47,826 |
| VIII | 83 | 116 | 116,422 |
| VIII - a | 83 | 110 | 84,559 |

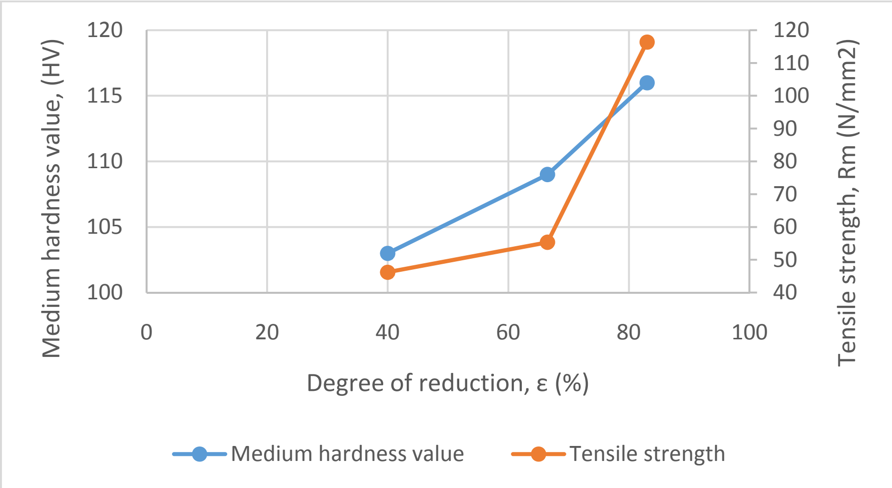


Figure3. Dependence of hardness and tensile strength of samples on the degree of reduction for the I series of samples

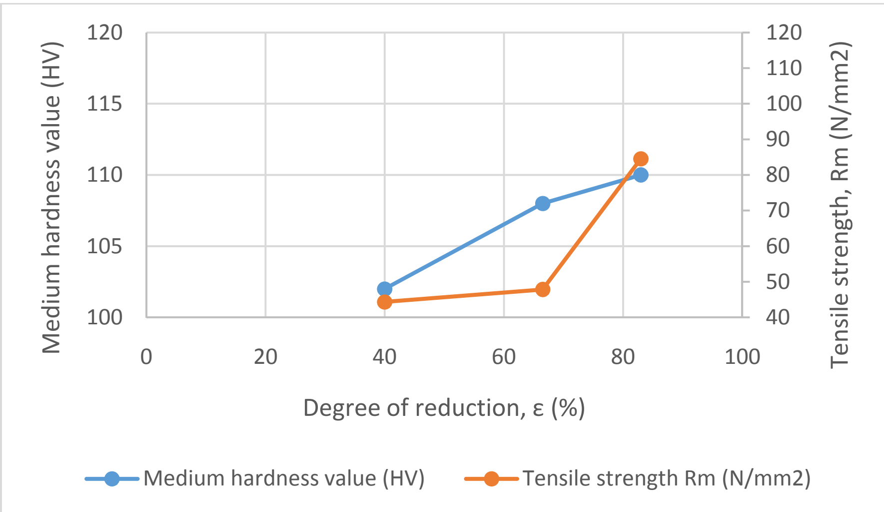


Figure4. Dependence of hardness and tensile strength of samples on the degree of reduction for the II series of samples

The diagrams show that as the total reduction increases, both the hardness and the tensile strength increase.

In the first series of samples, higher values of hardness and tensile strength were observed compared to the second series of samples.

The minimum hardness values, 102 HV and 103 HV, were obtained for samples deformed with a reduction degree of 40%, while the maximum values, 110 HV and 116 HV, were obtained at a reduction degree of 83%.Tensile strength has values of 44 ($N/mm^2$) and 46 ($N/mm^2$) to a maximum of 116 ($N/mm^2$) and 84.5 ($N/mm^2$).

The measured values of hardness and tensile strength for the first series of samples are higher than the measured values of hardness and tensile strength for the second series of samples at given degrees of reduction.

## 4. CONCLUSION

Based on the obtained results, the following conclusions can be drawn:

- By rolling copper strips, samples less than 0.7 mm thick can be obtained, without flaking, the strips have smooth surfaces, uniform widths along the length, uniform thicknesses along the length, and the edges are smooth and without cracks.
- With increasing degree of reduction, the tensile strength and hardness of the samples increase. Up to the degree of deformation of 66.5%, the tensile strength and hardness of the samples increase slightly, while at a higher degree of reduction than 66.5%, the growth is much more pronounced.
- The measured values of hardness and tensile strength for the first series of samples are higher than the measured values of hardness and tensile strength for the second series of samples at given degrees of reduction.
- Higher values of hardness and tensile strength for samples rolled in the first series compared to the hardness and tensile strength of samples rolled in the second series, are probably due to either slightly shorter heating of samples in the furnace or longer retention of samples in the charcoal box after removal from the furnace and a longer time of transferring samples from the box to the rolling machine.

## 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 451-03-9/2021-14/ 200131.*

## REFERENCES

[1] M. El Mehtedi, D. Lai, R. Almehtedi, M. Carta, P. Buonadonna, F. AymerichH, ESAFORM 2021. MS05 (Joining), 10.25518/esaform21.942.
[2] Q. Zhang, Mechanical Behavior of of Cu/Al multilayers fabricated by Accumulative Roll-Bonding (ARB) processing (Master Work), University of Nevada, Reno (2013).
[3] M. Miskovic, B. Miskovic, Teorijaplastičneprerademetala, Univerzitet u Beogradu, TMF Beograd, Beograd (1977).
[4] A. I. Celikov, TeorijaRascetaUsilij v ProkatnihStanah, Metallurgizdat, Moskva (1962).
[5] S. Zlatanovic, Uticajtermomehaničkihparametaraprerade na svojstvaviseslojnebakarnetrake
[6] (Diplomski rad), Univerzitet u Beogradu, TehnickiFakultet u Boru, Bor (2000).

ISBN 978-86-6305-119-5