



MINING AND METALLURGY INSTITUTE BOR
and
TEHNICAL FACULTY BOR, UNIVERSITY OF BELGRADE



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**International October
Conference**

**5rd International October
Conference on Mining
and Metallurgy**

PROCEEDINGS

Editors:
Ana Kostov
Milenko Ljubojev

3 – 5 October 2022. Hotel "Albo" Bor, Serbia



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TABLE OF CONTENTS

PLENARY LECTURES

Nikhil Dhawan

RECYCLING OF ELECTRONIC WASTE FOR RECOVERY OF
THE METALLIC VALUES 3

Aleksandra Ivanovic

APPLICATION OF THE SIMPLEX METHODS FOR TESTING THE INFLUENCE OF
COLD DEFORMATION LEVELS, ANNEALING TEMPERATURE AND CHEMICAL
CONTENT ON THE MECHANICAL CHARACTERISTICS OF SOME ALLOYS OF
THE Pd-Au SYSTEM 5

Saša Stojadinović, Dejan Petrović

ECONOMIC JUSTIFICATION FOR EXPLOITATION
THE BORON MINERALS IN BALJEVAC 9

Mirko Stijepović

APPLICATION OF OPTIMIZATION IN THE INDUSTRIAL PROCESSES 13

GEOLOGY, MINING AND MINERAL PROCESSING

Tamara Maričić, Marijana Pantić, Marina Nenković-Riznić

THE CRITERIA AND INDICATORS FOR DEFINING THE SOCIAL ASPECTS
IN SPATIAL PLANNING OF MINING REGIONS 19

*Radmilo Rajković, Daniel Kržanović, Miomir Mikić,
Milenko Jovanović, Emina Požega*

FORMATION OF A REACTIVE MATERIAL DUMP FROM
THE "ČUKARU PEKI" MINE NEAR BOR 25

*Daniel Kržanović, Radmilo Rajković, Milenko Jovanović,
Miomir Mikić, Sandra Milutinović*

MEDIUM-TERM PLANNING OF COPPER ORE EXPLOITATION AT
THE OPEN PIT VELIKI KRIVELJ NEAR BOR, SERBIA 29

*Sandra Milutinović, Milena Kostović, Ivana Jovanović,
Miomir Mikić, Daniel Kržanović*

DETERMINATION THE ADVANTAGE OF SOLUTION IN EASTERN SERBIA USING
THE FTOPSIS METHOD AND COMPARISON WITH THE TOPSIS METHOD 33

Snežana Ignjatović, Milanka Negovanović

DEFINING THE LOCATION AND DIP OF MAGNETIC ANOMALY SOURCES
APPLYING THE MATHEMATICAL TRANSFORMATION 39

Ivan Jovanović, Mladen Supić, Katarina Milivojević, Dušan Tašić

VENTILATION AND DISCHARGE SYSTEMS IN THE MINES WITH
THE UNDERGROUND EXPLOITATION OF NON-FERROUS METALS 43



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3 - 5 October 2022, Bor, Serbia

<https://ioc.irmbor.co.rs>

<i>Srdana Magdalinović, Silvana Dimitrijević, Aleksandra Ivanović, Stevan Dimitrijević, Stefan Đorđević</i> APPLICATION OF MINERAL PROCESSING METHODS IN RECYCLING THE WASTE PRINTED CIRCUIT BOARDS	47
<i>Lidija Đurđevac Ignjatović, Vesna Krstić, Vanja Đurđevac, Dragan Ignjatović</i> THE USE OF CEMENT PASTE IN THE MINING INDUSTRY AND ECOLOGY	51
<i>Dragan Ignjatović, Dušan Tašić, Vanja Đurđevac, Lidija Đurđevac Ignjatović</i> WICKHAM AND BIENAWSKI ROCK CLASSIFICATION IN MINING	55
<i>Katarina Milivojević, Mladen Supić, Ivan Jovanović, Dušan Tašić</i> METHODS OF DEFINING THE SWELING VOLTAGE AT EXPANSIVE SOILS	59
<i>Sanja Petrović, Grozdanka Bogdanović</i> THE EFFECT OF ALCOHOL ON LEACHING BY HYDROGEN PEROXIDE IN SULFURIC ACID SOLUTION	63
<i>Vladan Kašić, Slobodan Radosavljević, Vladimir Simić, Ana Radosavljević-Mihajlović, Jovica Stojanović, Slavica Mihajlović, Melina Vukadinović</i> PRELIMINARY GENETIC MODEL OF ZEOLITIC TUFF DEPOSITS IN THE TERTIARY BASINS OF SERBIA	67
<i>Sladana Krstić, Sanja Petrović, Ivana Jovanović, Slavica Miletić, Emina Požega, Daniela Urošević, Lidija Kalinović</i> APPRAISAL OF USABILITY THE DISINTEGRATED GRAVELLY SANDSTONE (TO THE GRADE OF NATURAL MIXTURE OF SAND AND GRAVEL)	71
<i>Ivana Jovanović, Sandra Milutinović, Mile Bugarin, Igor Svrkota, Dragan Milanović</i> COMPARISON OF THE SAG MILL POWER CALCULATION BY DIFFERENT METHODS	75
<i>Ivana Jovanović, Vesna Conić, Ana Kostov, Daniel Kržanović, Sandra Milutinović</i> EXAMPLE OF THE ANN CONTROL SYSTEM FOR THE FLOTATION PLANT	79
<i>Ivana Jovanović, Jasmina Nešković, Sonja Milićević, Milenko Ljubojev, Predrag Ivanović</i> DEPENDENCE OF THE OVERFLOW PARTICLE SIZE ON THE INLET SLURRY PRESSURE OF THE INDUSTRIAL HYDROCYCLONE	83
<i>Jovica Sokolović, Zoran Štirbanović, Ivana Ilić, Sandra Vasković</i> APPLICATION OF A COPPER SLAG AS A CONSTRUCTION MATERIAL	87
<hr/> METALLURGY, MATERIAL SCIENCE, TECHNOLOGY AND CHEMISTRY <hr/>	
<i>Zoran Karastojković, Ana Kostov, Radiša Perić</i> REASONS FOR BRAZING WITH COPPER FILLER METAL ALLOYED WITH THE COPPER (I) AND IRON (III) OXIDES	93
<i>Srdan Matijašević, Veljko Savić, Vladimir Topalović, Jovica Stojanović, Jelena Nikolić, Snežana Zildžović, Snežana Grujić</i> COMPLEX CRYSTALLIZATION OF THE POTASSIUM-NIOBIUM-GERMANATE SYSTEM ...	97
<i>Veljko Savić, Vladimir Topalović, Jelena Nikolić, Srdan Matijašević, Snežana Zildžović, Snežana Grujić</i> SINTER-CRYSTALLIZATION OF COAL FLY ASH BASED GLASS	101



<i>Nebojša Tadić, Žarko Radović</i> THE EFFECTS OF INITIAL PROFILE ON THE SHAPE OF COLD ROLLED STRIPS	105
<i>Žarko Radović, Nebojša Tadić, Sanja Šćepanović</i> THE EFFECT OF CHEMICAL COMPOSITION ON THE EAF DUST RECYCLING	111
<i>Ana Petrović, Radmila Marković, Emina Požega</i> STRUCTURE AND PROPERTIES OF CARBON NANOTUBES: A REVIEW	115
<i>Mirjana Stojanović, Milan Adamović, Jasmina Kustura, Enita Kurtanović, Muhamed Harbinja</i> MULTIFUNCTIONAL FERTILIZER BASED ON PYROPHYLLITE IN ACCORDANCE WITH THE REGULATION EU 2019/1009	119
<i>Emina Požega, Saša Marjanović, Milijana Mitrović, Milenko Jovanović, Ana Petrović, Radmilo Rajković, Slavica Miletić</i> ELECTRONIC TRANSPORT PROPERTIES OF THE Bi _{0.5} As _{1.5} Te _{2.98} Se _{0.02} SINGLE CRYSTAL: PART I	123
<i>Emina Požega, Anja Radičević, Danijela Simonović, Ana Petrović, Zdenka Stanojević Šimšić, Radmilo Rajković, Miomir Mikić</i> ELECTRONIC TRANSPORT PROPERTIES OF THE Bi _{0.5} As _{1.5} Te _{2.98} Se _{0.02} SINGLE CRYSTAL: PART II	127
<i>Franjo Kozina, Zdenka Zovko Brodarac, Luka Zeljko, Barbara Tubić Bulat, Primož Mrvar, Almir Mahmutović, Snježana Zeljko</i> TECHNOLOGICAL DEVELOPMENT OF THE CASTING PROCESS FOR THE THIN-WALLED GRAY CAST IRON	131
<i>Zdenka Stanojević Šimšić, Ana Kostov, Aleksandra Milosavljević, Emina Požega</i> CHARACTERISATION OF THE CuAlAg ALLOYS WITH 90 at. % Cu	135
<i>Vladimir Topalović, Srdan Matijašević, Jelena Nikolić, Veljko Savić, Marija Došić, Snežana Grujić</i> THE EFFECT OF La ₂ O ₃ ADDITION ON THE CRYSTALLIZATION CHARACTERISTICS OF POLYPHOSPHATE GLASSES	139
<i>Anja Antanasković, Dragan Radulović, Mladen Bugarčić, Tatjana Šoštarić, Vladimir Adamović, Zorica Lopičić, Milan Milivojević</i> IMMOBILIZED BENTONITE IN THE ALGINATE MATRIX – EFFICIENT SORBENT OF BRILLIANT GREEN	143
<i>Marko Pavlović, Marina Dojčinović, Aleksandar Sedmak, Igor Martić, Filip Vučetić, Zagorka Acimović</i> SYNTHESIS AND CHARACTERISATION OF THE MULLITE-BASED PROTECTIVE COATINGS	147
<i>Ana Kostov, Zdenka Stanojević Šimšić, Aleksandra Milosavljević, Ivan Jovanović</i> MICROSTRUCTURAL ANALYSIS OF CuAlAu ALLOYS	151
<i>Milijana Mitrović, Saša Marjanović, Biserka Trumić, Jasmina Petrović, Emina Požega, Miloš Janošević</i> INFLUENCE OF THERMO-MECHANICAL PROCESSING PARAMETERS ON THE TENSILE STRENGTH OF COPPER WIRE PRODUCED BY THE "UP CAST" PROCESS	155



<i>Saša Marjanović, Milijana Mitrović, Emina Požega, Biserka Trumić, Miloš Janošević</i> HARDNESS OF BIMETALLIC STRIP Cu – Č.4571 AFTER THE COLD ROLLING AND ANNEALING	161
<i>Milijana Mitrović, Saša Marjanović, Jasmina Petrović, Emina Požega, Miloš Janošević</i> INFLUENCE OF CHEMICAL COMPOSITION ON THE QUALITY OF CASTINGS OBTAINED BY THE EASY MELTING MODELS	165
<i>Silvana B. Dimitrijević, Suzana Veličković, Filip Veljković, Slađana Alagić, Stevan P. Dimitrijević, Aleksandra T. Ivanović, Saša Ivanović</i> CHARACTERIZATION OF THE GOLD MERCAPTOTRIAZOLE COMPLEX USING THE TANDEM QUADRUPOLE MASS SPECTROMETRY (TQD)	169
<i>Vesna Marjanović, Radmila Marković, Aleksandra Ivanović</i> SCANNING ELECTRON MICROSCOPY (SEM) METHOD IN A COMBINATION WITH THE ENERGY-DISPERSIVE SPECTROSCOPY (EDS) FOR ANALYSIS THE SURFACE OF HYDROUS IRON OXIDE-IMPREGNATED HYBRID POLYMER USED FOR SELENIUM ADSORPTION	173
<i>Vesna Marjanović, Radmila Marković, Silvana Dimitrijević, Zoran Stevanović</i> ANALYSIS THE SURFACE OF MODIFIED LIGNIN BASED MICROSPHERES USED FOR SELENIUM ADSORPTION BY THE SEM-EDS ANALYTICAL METHOD	177
<i>Ionelia Voiculescu, Victor Geanta, Radu Stefanoiu, Diana Chioibas, Andrei Popescu, Nicu Scarisoreanu, Emilia Binchiciu</i> CHARACTERIZATION OF ALUMINA COMPOSITE THIN COATINGS MADE BY THE DIRECT LASER DEPOSITION ON A HIGH ENTROPY ALLOY	181
<i>Rustam Sharipov, Essen Suleimenov, Bolysbek Utelbayev, Galymzhan Maldybayev, Maxat Myrzakhanov</i> APPLICATION OF COMBINED ELECTROCHEMICAL REACTIONS IN METALLURGICAL TECHNOLOGIES	187
<i>Rustam Sharipov, Maxat Myrzakhanov, Essen Suleimenov, Bolysbek Utelbayev</i> CORROSION: PROBLEMS AND CHALLENGES	191
<i>Vesna Conić, Suzana Dragulović, Dragana Božić, Dragan Milanović, Ivana Jovanović, Srđan Stanković, Jelena Avdalović</i> CORRELATION OF Fe ²⁺ WITH Cu ²⁺ AND Zn ²⁺ IN THE BIOLEACHING PROCESS	195
<i>Vesna Conić, Suzana Dragulović, Dragana Božić, Dragan Milanović, Ivana Jovanović, Srđan Stanković, Jelena Avdalović</i> COMBINATION OF CHEMICAL AND BIOLEACHING PROCESS FOR Cu AND Zn RECOVERY FROM THE SEDEX TYPE ORE	199

ENVIRONMENTAL PROTECTION

<i>Vesna Marjanović, Aleksandra Ivanović, Nevena Marjanović</i> SIGNIFICANCE OF THE SWOT ANALYSIS FOR MONITORING THE IMPROVEMENTS OF APPLICATIONS THE ISO 14001: 2015 STANDARD	205
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<i>Milenko Jovanović, Daniel Kržanović, Radmilo Rajković, Miomir Mikić, Emina Požega</i> ADVANTAGES AND PURPOSE OF BIOCOMPOSITE GEOGRIDS	209
<i>Milenko Jovanović, Daniel Kržanović, Radmilo Rajković, Miomir Mikić, Emina Požega</i> APPLICATION OF GEOGRIDS IN RECULTIVATION MEASURES OF DEGRADED LAND	213
<i>Miomir Mikić, Emina Požega, Radmilo Rajković, Milenko Jovanović, Daniel Kržanović</i> RECULTIVATION OF DEGRADED AREAS FORMED BY DEPOSITION OF TAILINGS AT THE FLOTATION TAILING DUMP “STUBIČKI POTOK”, LEPOSAVIĆ	217
<i>Viša Tasić, Tatjana Apostolovski-Trujić, Ivan Lazović, Nikola Mirkov, Zvonko Damjanović</i> AUTOMATIC METEOROLOGICAL STATION (AMS/2022) BASED ON THE LOW-COST SENSORS (part 1)	221
<i>Viša Tasić, Tatjana Apostolovski-Trujić, Ivan Lazović, Nikola Mirkov, Zvonko Damjanović</i> AUTOMATIC METEOROLOGICAL STATION (AMS/2022) BASED ON THE LOW-COST SENSORS (part 2)	225
RELATED FIELDS: MECHANICAL ENGINEERING, CIVIL ENGINEERING, ARCHITECTURE, ELECTRONICS, INFORMATICS, MANAGEMENT, ETC.	
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<i>Nenad Marković, Slobodan Bjelić, Filip Marković</i> SIMULATION MODEL OF DYNAMIC STATES IN AN ASYNCHRONOUS MACHINE WITH A SHORT-CIRCUITED ROTOR	231
<i>Slavica Miletić, Marko Trišić, Ana Milijić, Emina Požega, Sladana Krstić</i> AHP ANALYSIS OF THE COMPETENT LABORATORY ACCREDITATION STAFF	237
<i>Tanja Stanković, Nikola Stanić, Dejan Bugarin, Aleksandar Milijanović</i> ECONOMIC ANALYSIS OF INVESTMENTS IN CAPACITY INCREASE TO 1,000,000 TONS OF LIMESTONE AT THE KAONA SURFACE MINE NEAR KUČEVO	241
INDEX OF AUTHORS	247

HARDNESS OF BIMETALLIC STRIP Cu – Č.4571 AFTER THE COLD ROLLING AND ANNEALING

Saša Marjanović¹, Milijana Mitrović¹, Emina Požega²,
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Abstract

Samples of bimetallic strip Cu-Č.4571 were cold rolled with different reduction degrees, and the ones deformed with the highest reduction degrees were annealed afterwards at different temperatures for different periods of time. The values of the hardness of the layers of the bimetallic strip were obtained as a function of the degree of deformation, and the annealing temperature. Global flow of curves hardness - total deformation, increases, where this flow, for both curves, can be divided into three parts. A global decrease in hardness was observed with an increase in the annealing temperature, for all periods of time, in both the steel layer and the copper layer.

Keywords: bimetallic strip, hardness, deformation degree, annealing

1 INTRODUCTION

Bimetals are widely used in the industry thanks to a combination of different properties in one material due to saving the expensive scarce metals, and their specific properties which the separated metals-components do not have.

In a bimetal, the expensive metals and alloys are used as the plating materials, with thickness of up to 25% of the bimetal thickness. Thanks to that, it is possible to get the relatively cheap materials with required properties where a performing layer keeps the properties that it has got before joining into bimetal, while cheaper, the basic material acts as a carrying material that provides the required mechanical properties.

Corrosion-proof bimetals with copper as a plating layer are used more and more.

Cold rolling of a plated strip is a final operation in the plastic processing in all cases when the enhanced strength and deformation resistance are required [1-5].

2 EXPERIMENTAL

In this investigation, samples cut from a two-layer board Cu-Č.4571 (steel: C – 0.1%; Cr – 18%; Ni – 9%) 2 mm thick, obtained by the plating by explosion, were used. The initial thickness of steel in them was 1.05 mm, and copper 0.95 mm.

Prior to rolling of a bimetal strip, the gap between the working rolls was set to 2 mm, and then the strip was let between them for a few times till the total deformation of 10% was reached.

In order to simplify it, it was accepted that the deformation for a single pass was 2.5%. After the deformation of 10%, the total thickness and layers thicknesses were measured on various spots.

The same procedure was repeated for the total deformations of 20%, 30%, 40%, 50%, 60%, 70%, 80% and 85%.

Samples deformed with the maximum deformation degree, $\epsilon_{\max}=85\%$, were subjected to annealing.

The annealing was done in a protective atmosphere of nitrogen at temperatures of 700, 750 and 780 °C, for periods of 1,5; 2 and 2,5 h for all temperatures.

Hardness measurements were performed after all degrees of deformation and annealing.

The experimental flow is shown schematically in Figure 1.

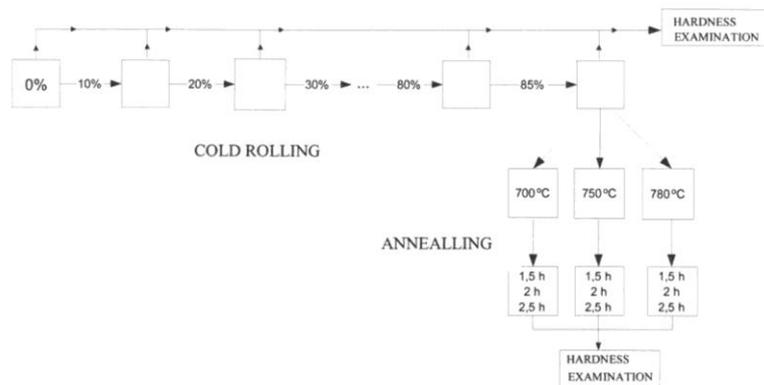


Figure 1 Schematic diagram of the experimental flow

3 RESULTS AND DISCUSSION

The obtained data for the hardness measurements, depending on the total deformation degree are given in Table 1 and Figure 2.

Table 1 Dependence of the hardness of bimetallic strip layers on the deformation degree

ϵ (%)	HV (daN/mm ²)	
	Č.4571	Cu
0	299	67.9
10	322.4	100.9
20	324.6	117
30	325.6	108.6
40	336.4	115.9
50	337.7	110.7
60	389.7	114.3
70	380.1	128.9
80	441.14	128.4
85	445.6	130.6

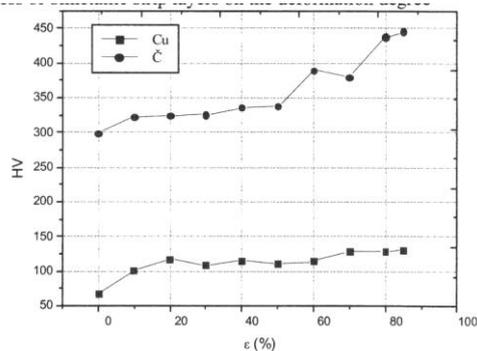


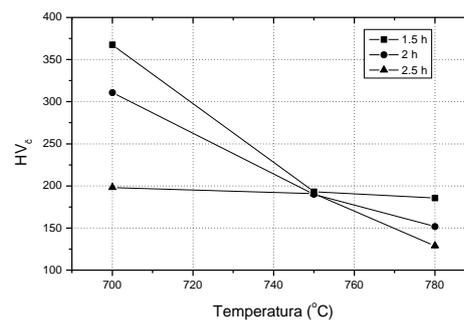
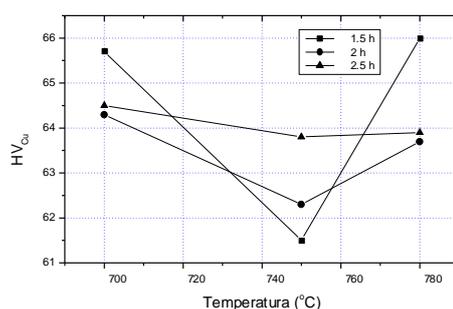
Figure 2 Diagram of dependence the hardness of the bimetallic strip layers on the deformation

Global flow of curves hardness - total deformation, increases, where this flow, for both curves, can be divided into three parts. In the first part of the curve, up to a deformation of about $\varepsilon = 20\%$, the hardness of both layers increases sharply, with a more pronounced increase in the hardness of copper layer, which can be explained by the higher rate of deformation strengthening of copper compared to steel. In the second part of the curve ($\varepsilon = 20 - 50\%$), the stagnation of increase in hardness is observed with the certain oscillations in the hardness values, which may be a consequence of the saw-tooth structure at the copper-steel junction. This saw-toothed structure is the result of steel penetration into a copper layer and vice versa due to the fusion by explosion. In the third part ($\varepsilon = 50 - 85\%$), there is an increase in hardness again with an increase in the deformation degree, and in this part the increase in hardness is more pronounced in steel because at these degrees of deformation, copper has almost reached its maximum hardness (about 130 HV).

The obtained test results, dependence of hardness (HV) from the annealing temperature and time are shown in Table 2, and diagrams in Figure 3 and Figure 4.

Table 2 Dependence the hardness of bimetallic strip layers on the annealing temperature and time

t(°C)	time (h)	HV (daN/mm ²)	
		Č.4571	Cu
700	1.5	367.7	65.7
	2	310.7	64.3
	2.5	198.0	64.5
750	1.5	193.0	61.5
	2	190.1	62.3
	2.5	190.7	63.8
780	1.5	185.7	66.0
	2	151.7	63.7
	2.5	128.7	63.9



Figures 3 and 4 Diagrams of dependence the hardness of bimetallic strip layers on the annealing temperature and time

On the diagram of dependence, the hardness on temperature and annealing time for a copper layer (Figure 3), it can be seen a decrease in hardness with increasing annealing



time at all annealing temperatures. However, when annealing is at 750°C, increasing the annealing time causes an increase in hardness of the bimetallic strip layer on the copper side. Also, after annealing at this temperature, the minimum hardness appears at all annealing times.

On the diagram of dependence, the hardness on temperature and annealing time for the steel layer (Figure 4), a decrease in hardness can be observed both with increasing annealing time and increasing annealing temperatures. This drop in hardness is more pronounced for annealing times of 1.5 and 2 hours up to temperature of 750°C, and annealing time of 2.5 hours, the decrease is more pronounced above this temperature.

4 CONCLUSION

As the degree of cold deformation increases, the hardness of layers of the bimetallic tape increases. Three areas can be observed on the hardness curves. In the first area, up to $\epsilon = 20\%$ the hardness of a copper layer increases more intensively. In the second area, at $\epsilon = 20 - 50\%$, the hardness of both layers increases less intensively, and in the third area ($\epsilon = 50 - 85\%$), the hardness of a steel layer increases more intensively.

During annealing of samples, cold deformed at 85% at temperatures of 700, 750 and 780°C for a duration of 1.5; 2 and 2.5 hours, the hardness of both layers of bimetal changes. The hardness of the steel layer decreases continuously at all temperatures and annealing times. In the case of the copper layer, the minimum hardness occurs after annealing at temperature of 750°C, whereby an increase in hardness is observed at this temperature with the extension of the annealing time.

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