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

IOC 2022

International October Conference

53rd 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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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: 100 copies

CIP – Каталогизација у публикацији
Народна библиотека Србије, Београд

622(082)
669(082)

INTERNATIONAL October Conference on Mining and Metallurgy (53 ; 2022 ; Bor)
Proceedings / 53rd International October Conference on Mining and Metallurgy - IOC 2022, 3 % 5 October 2022, Bor ; [organizer] Mining and Metallurgy Bor and Technical Faculty in Bor, University of Belgrade ; editors Ana Kostov, Milenko Ljubojev. - Bor : Mining and Metallurgy Institute, 2022 (Bor : Grafomed-trade). - XV, 251 str. : ilustr. ; 25 cm

Tiraž 100. - Bibliografija uz svaki rad. - Registar.

ISBN 978-86-7827-052-9

a) Рударство - Зборници b) Металургија - Зборници

COBISS.SR-ID 74763529

Bor, October 2022

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

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

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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 cooper 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, ε_{max}=85%, were subjected to annealing.

The annealing was done in a protective atmosphere of nitrogen at temperatures of 700, 750 and 780 ^{o}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.

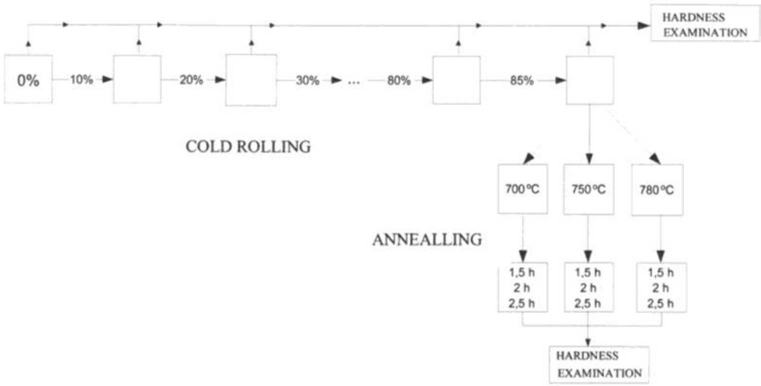


Figure 1 *Schematic diagram of the experimental flow*

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

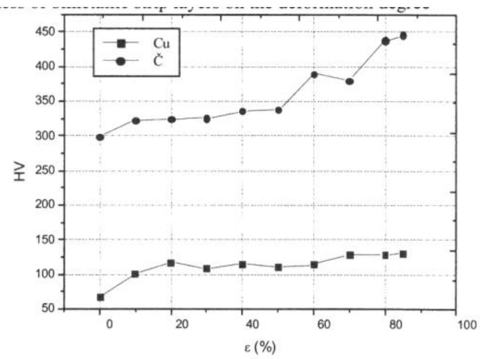


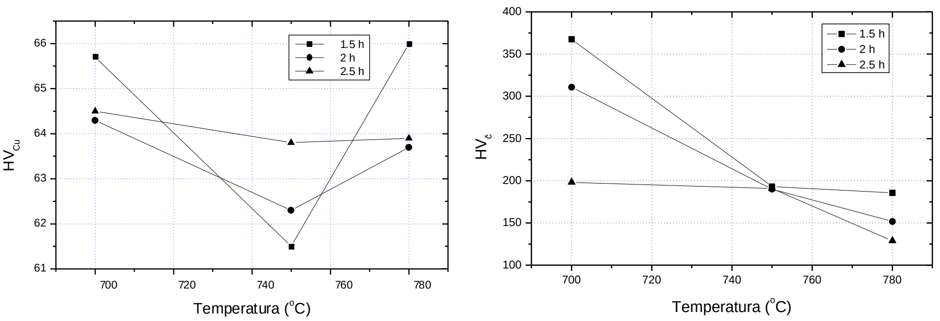
Figure 2 *Diagram of dependence the hardness of the bimetallic strip layers on the deformation*

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 ε = 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 (ε = 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 (ε = 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/mm²)	
		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 ε = 20% the hardness of a copper layer increases more intensively. In the second area, at ε = 20 - 50%, the hardness of both layers increases less intensively, and in the third area (ε = 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.

ACKNOWLEDGEMENTS

The research presented in this work 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 451-03-68/2022-14/200131, and Mining and Metallurgy Institute Bor with registration number 451-03-68/2022-14/200052.

REFERENCES

[1] B.G. Grinberg, Y.B. Knišev, Mnogoslojnije Metally v Tehnike, Znanije, Moskva, 1969. (In Russian).
[2] J.A. Vaccori, The Manu Roles of Clad Metals Design Engineering, January (1980) 55.
[3] J.C. Wright, New Materials for Sheet Metal Working – Part 3. Sheet Metal Industries, March (1976) 126.
[4] A. Kubeta, Present and Future of Explosive Cladding, Chemical Economy and Engineering Review, 7, 12 (1975) 1.
[5] A. Konon, V.H. Redorov, L.B. Pervulin, A.A. Bikov, Korrozionostojkij Bimetal – Mašinostroenie, Moskva, (1984). (In Russian).