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DEPENDENCE OF Al BRONZE SURFACED LAYERS ON THE POSTWELD THERMOMECHANICAL TREATMENT

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The research investigated properties of aluminum bronze welded to structural steel St 52-3 N. Surface material CuAl-A3 was welded in one and two layers. There were dimension, metallographic examination of structures and hardness measured before and after heat treatment and after pressurization of tested specimens. It was determined that the specimens achieved the best performance by welding two layers of surface material, by postweld heat treatment and by "hammering".

Key words: Al bronze, welding, thermomechanical treatment, microstructure, hardness

INTRODUCTION

Aluminum bronze, both forged and cast, can be welded [1]. In order to achieve good results, producers of filler materials recommend electric arc welding under protection of inert gas. As a rule, postweld heat treatment is recommended to remove residual stresses, as well as to improve corrosion resistance [2]. Al bronze has a low friction factor, which, in the conditions of metal/metal contact, can contribute to lowering of the scuffing risk. By assuring the adequate hardness of filler layer, it is possible to increase its wear resistance [3]. The paper presents properties of surfacing by welding in two layers with filler material CuAl-A3. Specimens were processed by postweld heat treatment and subjected to hardening by simulated "hammering" under different pressure loads. The research aim was to determine dependence of surfaced layer on selected parameters of thermomechanical processing by analyzing the structure and results referring to thickness and hardness of the surfaced layer.

THEORETIC DISCUSSION ABOUT ISSUES CONCERNING SURFACING OF Al BRONZE

The Figure 1 presents the diagram of Cu – Al condition with visible microstructural changes of the alloy with 10 % Al.

Within slow cooling (point G in the Figure 1), γ2 crystals occurred at temperatures of 565 - 400 °C, causing very fragile structure prone to corrosion. In real conditions of cooling, hardened alloy structures often do not meet expectations if analyzing the equilibrium phase diagram. "Poor" casting can be improved by heating above 565 °C in duration of two hours and pressured in water or air stream. At a room temperature, b and a crystals will be maintained in portions that depend on the cooling rate. The cooling rate must be appropriate to avoid formation of brittle γ_2 crystals. More a crystals will provide a greater ductility, and more residual b crystals will provide greater strength. Portions of a crystals in residual b crystals can be changed by postweld heat treatment, thus avoiding formation of γ_2 crystals [4].

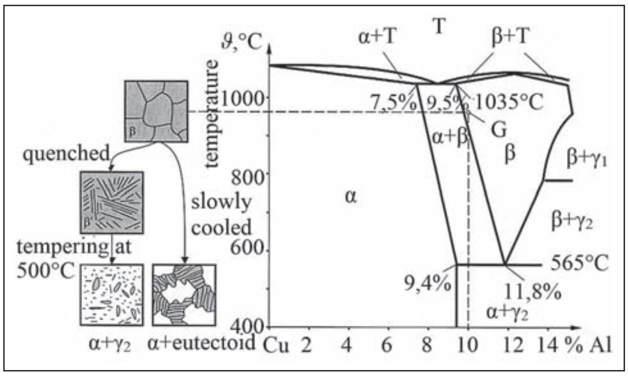

Figure 1 Diagram of Cu – Al condition with microstructural changes in alloy with 10 % Al [4]

With the development of technology and new types of filler material, there were preconditions made for more intensive usage of surfacing when producing parts for various purposes, when necessary to prevent transfer of carbon steel particles to corrosion resistant Cr-Ni steel.

EXPERIMENTAL PART

By Metal Inert Gas procedure, base material St 52-3 N [5] was surfaced with two layers of aluminum bronze CuAl-A3, according to AWS A5.7 class ER [6]. Surfacing was performed with the aim to minimize the amount or to avoid the presence of base material particles in the upper layer. Overview of chemical composition of the alloy used for the surfacing is given in the Table 1.

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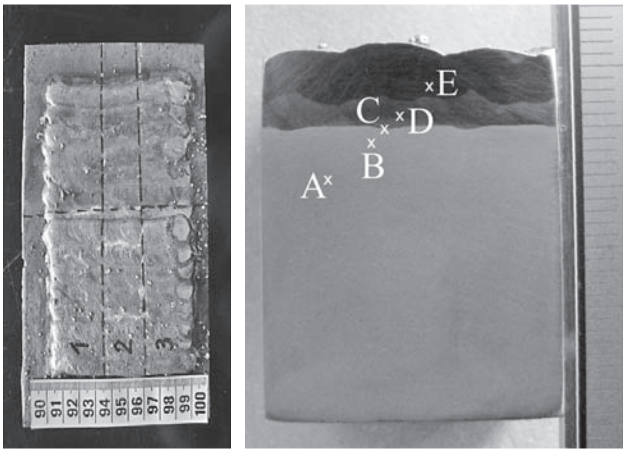
Table 1 **Composition of CuAl-A3 [6]**

CuAl-A3 [6]	Element				
	Cu	Al	Fe	Si	Rest.
Portion / wt. %	balan-ced	10,0 ÷ 10,5	2,0÷ 4,5	max 0,1	max 0,50



a) b)

Figure 2 Experimental surfaced layer
a) test plate;
b) characteristic cross-section of specimen (perpendicular to surfacing direction)

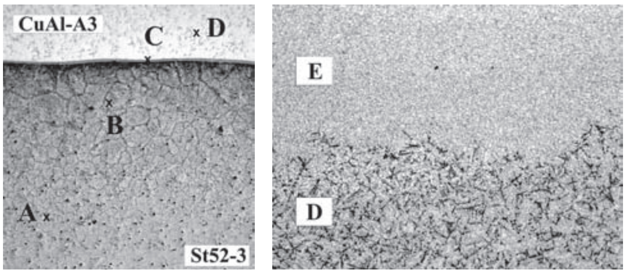
Parameters of surfacing aluminum bronze on steel were defined on the basis of recommendations of filler material producers. In order to perform experiment, the surfacing speed was 0,6 m/min, surfacing voltage was 22 V and current was 200 A. The base material was preheated to a temperature of 150 °C. Specimens were made in such a way to enable observation of the surface of cross-section area, perpendicular to the direction of the surfacing, as seen in the Figure 2.

There were three groups of specimens prepared out of the surfaced plate. Specimens were marked by 1, 2 and 3, as follows:

- the group 1 of specimens was not submitted to postweld heat treatment or any other treatment after surfacing;
- the group 2 of specimens was heat-treated after surfacing. Heat treatment was selected in accordance with the diagram of Cu-Al condition, as shown in the Figure 1. Heating was performed in electric chamber furnace, at 600 °C for 2 hours, and then cooled by air stream;
- the group 3 of specimens was heat-treated after surfacing and then pressured under 100 ÷ 400 kN with the aim to simulate „hammering“.

On the specimens it was necessary:

- to check the presence of base material particles in the first and second surfaced layer by metallographic analysis of cross-section,
- to measure dimensions and hardness by HV1 on the cross-section before and after heat treatment of specimens and after pressurization (“hammering”), in order to determine influences of thermomechanical process on the properties of surfaced layers.



a) b)

Figure 3 Characteristic microstructure of cross-section surfaced layer before heat treatment
a) Grund material - surfaced layer, corrosion with 2,5 % Nital, magn. 100 : 1
b) Surfaced layers, corrosion with CrS acid, magn. 200 : 1

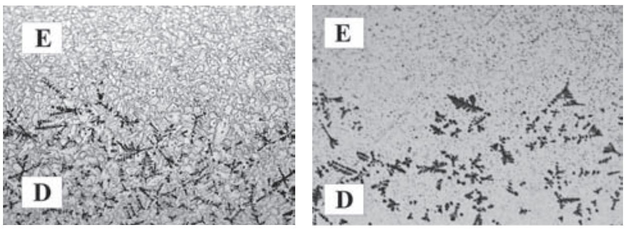
Metallographic analysis

The Figure 3 presents characteristic microstructure of specimen cross-section, as of the Figure 2b: A and B-base material; C- fusion line between base material and the first surfaced layer; D–the first surfaced layer; E–the second surfaced layer.

On the Figure 3b, it is visible that:

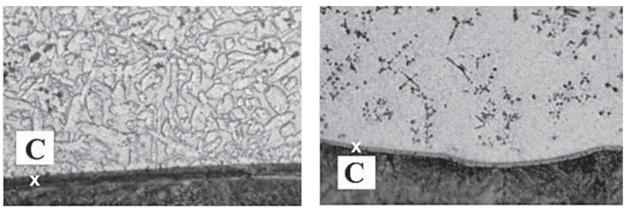
- in the first surfaced layer (area D), there was significant presence of base material particles, which took dendritic shape. These particles were relatively uniformly distributed throughout the cross-section of that layer;
- in the second surfaced layer (area C), presence of base material particles is negligible.

Microstructure of surfaced layer before heat treatment is shown in the Figure 4a, and after heat treatment in the Figure 4b. Fusion zones before and after heat treatment are presented in Figures 5a and 5b.



a) b)

Figure 4 Microstructure of surfaced layer
a) before heat treatment, corrosion with 2,5 % Nital, magn. 500 : 1
b) after heat treatment, corrosion with CrS acid, magn. 1 000 : 1



a) b)

Figure 5 Microstructures of fusion zone on cross-section
a) before heat treatment, corrosion with 2,5 % Nital, magn. 1 000 : 1
b) after heat treatment, corrosion with CrS acid, magn. 500 : 1

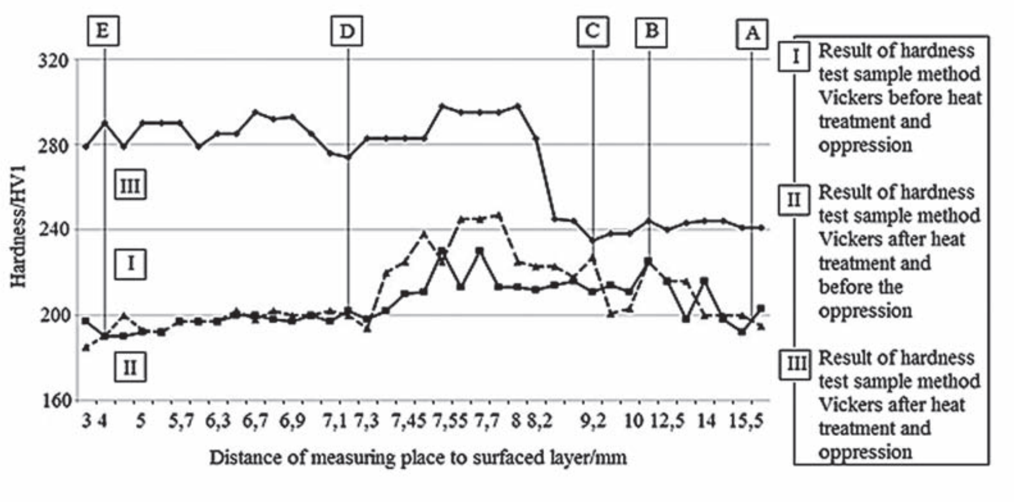


Figure 6 Diagram of hardness values on the cross-section of specimens

Measuring of hardness

Measuring of hardness was performed by the device Durimet „Leitz“, on the cross-section of specimens, perpendicular to the direction of the surfacing. Results are presented in the diagram in the Figure 6. Values of hardness were measured on three groups of specimens, as follows:

- on the first group of specimens after surfacing, and before heat treatment,
- on the second group of specimens after surfacing and after heat treatment;
- on the third group of specimens after surfacing, heat treatment and pressurization (“hammering“).

The testing machine Amsler was used to perform pressurization of surfaced layers in tested specimens. Pressure forces were within the range of 100 ÷ 400 kN. Pressurization with force of 300 kN resulted in significant increase of values for hardness if compared to the values of initial measurements. Results overviewed in the Figure 6 refer to measured values of final pressurization with force of 400 kN in duration of 5 seconds. Results of measured hardness of the first two groups of specimens, lines marked by I and II in the Figure 6, are quite similar. Measured hardness of the base material, marked by A in the Figure 6, are in the range of 190 ÷ 230 HV1. Measured hardness of the fusion zone, marked by C, and heat affected zone, marked by B in the same Figure 6, are in the range 230 ÷ 250 HV1. In the surfaced layer zone, marked by D and E in the same Figure 6, measured hardness was in the range of 180 ÷ 220 HV1. Measured hardness of the third group of specimens, as of the line marked by III on the Figure 6, was significantly higher if compared to results of the first two groups. In the zone of base material, marked by A in the Figure 6, measured hardness was 240 ÷ 250 HV1. In the fusion zone, marked by C, and in the heat affected zone, marked by B in the Figure 6, measured values for hardness were 290 ÷ 300 HV1. In the surfaced layer zone, marked by D and E in the Figure 6, measured values for hardness were 270 ÷ 295 HV1.

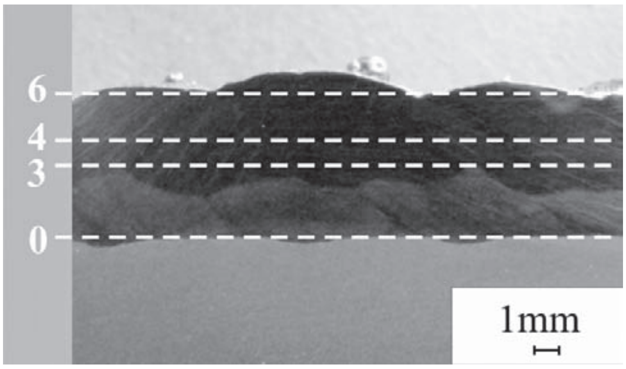


Figure 7 Results of dimensional control of surfaced layer cross-section

Measuring of surfaced layer dimensions

Measuring of thickness of the surfaced layer was performed directly on macroscopic sample. Measured values referring to thickness are shown in the Figure 7. Numbers along the line refer to measured values in millimeters. The line marked by 0 refers to the zone of bronze/steel fusion. The line 3 refers to the first layer thickness of 3 mm. The line 4 marks minimum thickness of the surfaced layer in millimeters, under which the surfaced layer should not be mechanically professed. The line 6 represents the thickness of “rough” surfaced layer achieved by selected surfacing parameters.

ANALYSIS OF RESULTS

By examining the microstructure of cross-section surfaced layer, as of the Figures 4a and 5, it is determined that the first surfaced layer contained significant portion of base material particles. In the second surfaced layer, portion of base material particles was negligible. Heat treatment after surfacing was required for several reasons. The most important reason is found in the fact that because of slow cooling, there were γ_2 brittle crystals formed in the surfaced layer, which are prone to corrosion. Results of hardness, measured by the HV1 method before and after heat treatment, indicate the increase of hardness value in the fusion zone, marked by C. It was noticed that there were no changes in levels of hardness in specimens after heat treatment if compared to those achieved after surfacing. The increase of hardness levels is noticed after pressurization in the whole cross-section of specimen. The most significant increase of hardness occurred in the zones marked by D and E. Fusion zone marked by C in the Figure 6 is characterized by narrow and straight configuration and relatively high hardness. By examining results of dimensional control of cross-section surfaced layer, it was determined that thickness of layer of ≈ 6 mm was possible to be achieved by double-layer surfacing.

CONCLUSION

Experiment results indicate the need for careful selection of parameters of surfacing, parameters of post-weld heat treatment and size of the force while „hammering“ the surfaced layer. Analysis of experiment results led to conclusion that selection of parameters can enable achievement of surfaced layer with properties that can be also ”insulated”, in the sense of separating carbon steel from corrosion-resistant Cr-Ni steel in conditions of adhesion contact. Homogenized upper layer of aluminum bronze without base material particles can be achieved by surfacing and machine processing of surfaced layer to the thickness of ≈ 6 mm. If wanting to process the surfaced layer by machine to lower thickness, for example under 4 mm, it would be necessary to determine maximum thickness of the first surfaced layer. That thickness would represent a limit under which surfaced layer should not be processed, and it would be necessary to perform surfacing in two layers. In addition, further research can be directed towards checking of influences of fusion zone on the properties of surfaced layers under conditions of tensile and shear stresses.

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Note: Responsible person for English translation is prof. Martina Šuto (J.J. Strossmayer University of Osijek) and prof. Marina Karšić