SELECTED PROPERTIES OF ALLOY 400 PROTECTIVE COATINGS COVERING CuZn30 BY ESD TECHNIQUE

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Abstract

This paper presents the results of investigation considering the morphology of surface layers produced by electro-spark deposition (ESD). It is a pulsed micro-welding process used for small scale and precision repair of high value worn or misfabricated components. The consumable electrode material is deposited onto the work piece by means of electric sparks in a manner reverse to spark erosion. In the electro-spark deposition process, the electrode is the anode and the work piece is the cathode. It has been found that the surface layer produced by ESD has good criteria resistance by changing the process parameters and promising protective properties. In the experiment, the coatings were electro-spark deposited with using an Alloy 400 electrode (the anode) - onto samples made of CuZN30 Bras (the cathode). The morphology of the layers is shown in the OM and SEM photomicrographs. As a result of the electric discharge, diffusion of individual elements was observed. For diffusion observations, ESD analyzes were performed on the cross-section of the produced layer. Microhardness measurements were also carried out.

Keywords: Electro-spark deposition, ESD, alloy 400, protective coatings, microstructure

1. INTRODUCION

Electro-spark deposition (ESD) [1-6] is particularly suitable for repairing small and shallow defects, but it is not suitable for large defects, since the process is slow and the maximum thickness of the coating is about 2mm. ESD can also be considered as a process to increase the wear and the erosion resistance of small surface [6-11]. Many applications require the components to have excellent surface performance, such as corrosion resistance and wear resistance as well as the build up of worn or damaged areas on parts. To meet these requirements, some components are built with specific materials, compromising other properties and cost. The short duration of the electrical pulse allows for an extremely rapid solidification of the deposited material and results in an exceptionally fine-grained, homogeneous coating that approaches to an amorphous structure. The low heat input eliminates deleterious thermal stresses or changes in metallurgical structure [12-16], otherwise known as the HAZ, allowing it to be considered for heat-sensitive applications. ESD is also an environmentally friendly process, and the deposition of toxic materials can be accomplished with the use of a fume hood to capture any dangerous gases that may evolve. The compact ESD equipment is so relatively easy to operate that it could be incorporated for use on-site and perform intermediate-level maintenance activities [17-21]. Components that would normally have to be removed from the technical system could also be repaired on-site, eliminating costs and waste generation. There are also significant environmental benefits associated with the implementation of ESD technology including the elimination of brush and hard chromium plating and the wastes associated with its use. ESD silverin coatings should give possibility to raise functional parameters of elements made of CuZn30. They can also be used to regenerate worn bras elements.

2. EXPERIMENT

2.1. Materials and layer fabrication

For the tests there was selected an Alloy 400 - member of Nickel-Copper alloy series produced by Deutsche Nickel GmbH include Silverin 400 (Alloy 400, 2.4360), Silverin 405 (Alloy 405, 2.4363) and Silverin 500 (Alloy K-500, 2.4375). These alloys retain relatively high mechanical properties and excellent corrosion resistance at both low and high temperatures. Due to their excellent resistance to sea-water and other corrosive media, these alloys are typically found in Oil & Gas, as well as Chemical industry applications. In the experiment, the coatings were electro-spark deposited with using an Alloy 400 electrode with a cross-section of 2 x 3 mm (the anode) - onto samples made of CuZN30 Bras (the cathode). The chemical composition of CuZn30 is shown in **Table 1** and the chemical composition of alloy 400 electrode is shown in **Table 2**. The chemical composition of used materials allows for good adhesion of the applied layer. Based on previous experience, the values of machining parameters have been selected.

Table 1 The chemical composition of CuZn30

element	Cu	Pb	Al	Fe	Ni	Sn	Zn
%	69.0 - 71.0	max. 0.05	max. 0.02	max. 0.05	max. 0.3	max. 0.1	balance

Table 2 The chemical composition of alloy 400 electrode

element	Ni	Cu	Fe	C	Mn	S	Si
%	63.0 min	28.0-34.0	2.5 max	0.3 max	2.0 max	0.024 max	0.05 max

The equipment used for electro-spark deposited was specially designed for the experiment. Reaching our current experience, based on previous research, following parameters were assumed to be optimal for ESD technique: voltage U = 600 V, capacitor volume C = 50 μF and 150 μF, frequency of the spark-intervals F = 50 Hz.

2.2. Test methods

After ESD coatings, the specimens were sectioned, placed in cold setting acrylic resin (VariDur 10) and prepared for microscopic analysis with a STRUERS automatic polishing machine. The final polishing was performed using a 0.05 μm Al_2O_3 (Microdiament) suspension. The preparation of the specimens for the OM and SEM examinations did not include etching. The structure analysis was conducted using a JEOL JSM 7100F (field emission) scanning electron microscope. The chemical composition of the specimens was studied by means of an EDS spectrometer Oxford X-MAX [22-25]. Microhardness tests were carried out by using INNOVATEST Nexus 4504 with Vickers indenter. Applied load was 0.1961 N for 15 s. The indentations were positioned at regular intervals in the transverse direction across the surface layer, from the fusion zone up to the base metal.

3. RESULTS

On the cross-section of the produced layer with use of a 50 μF capacitor, there was observed significant porosity with a large number of cracks. Observations of the layer formed using a 150 μF capacitor revealed much better coating quality. **Figure 1** shows SEM image of the cross-sections of the specimen. The photograph of the microstructure exhibits a distinct boundary between the coating and the substrate coating and visible pores. Electro coating thickness obtained for the test samples was about 40 to 60 μm. Chemical composition tests for surface layer have been carried out using X-ray microanalysis. **Figure 2** shows analysis of chemical composition in points, and we can observe the diffusion of the electrode in to material. **Table 3** shows results marked on **Figure 2a** and **Table 4** shows results marked on **Figure 2b**. **Figure 3** shows analysis of linear distribution elements in cross-section of analysed samples. The mechanical behaviour of the coatings was characterized by measurement of micro-hardness. Alloy 400 NiCu coating presented a hardness around 230 HV; **Figure 4** shows intender view on BM, FZ and layer on samples 150 μF. During the ESD process, some heat is added, raising the temperature of local spots on the electrode surface to melting point; however, the heat does not raise the temperature of the substrate high enough to melt it significantly or cause substantial microstructural changes. Also, the much greater thermal sink in the substrate, and the pulsed nature of the spark results in transitory melting of the substrate and formation of very small HAZ adjacent only, to the surface with a depth of about 2 μm. Due to high conductivity of the substrate and the fact, that the time between the sparks is relatively very long to the sparks duration, it allows for quick dissipate the heat supplied to the substrate.

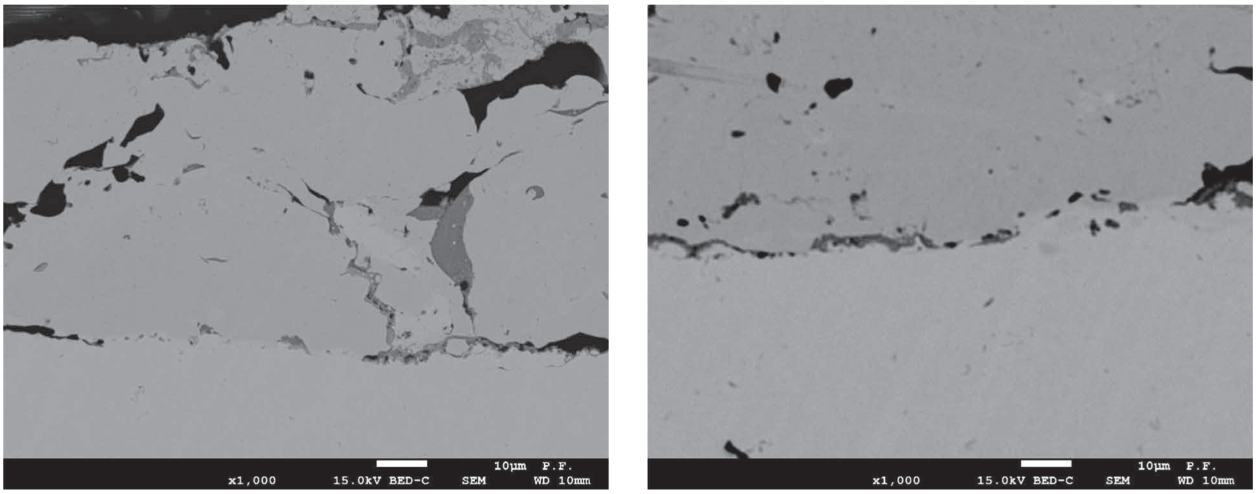

Figure 1 SEM micrographs of sample (a) 50 μF and (b) 150 μF, magnification 1000x

Table 3 Results analysis of chemical composition in points marked on **Figure 2a**

Result Type	**Weight %**					
Spectrum Label	**Si**	**Mn**	**Fe**	**Ni**	**Cu**	**Total**
1 1		0.42	1.82	61.56	36.19	100.00
1 2	0.24	0.69	2.05	61.50	35.51	100.00
1 3		0.43	1.76	57.13	40.68	100.00
1 4			1.58	56.08	42.34	100.00

Table 4 Results analysis of chemical composition in points marked on **Figure 2b**

Result Type	**Weight %**		
Spectrum Label	**Cu**	**Zn**	**Total**
1	68.66	31.34	100.00
2	68.41	31.59	100.00

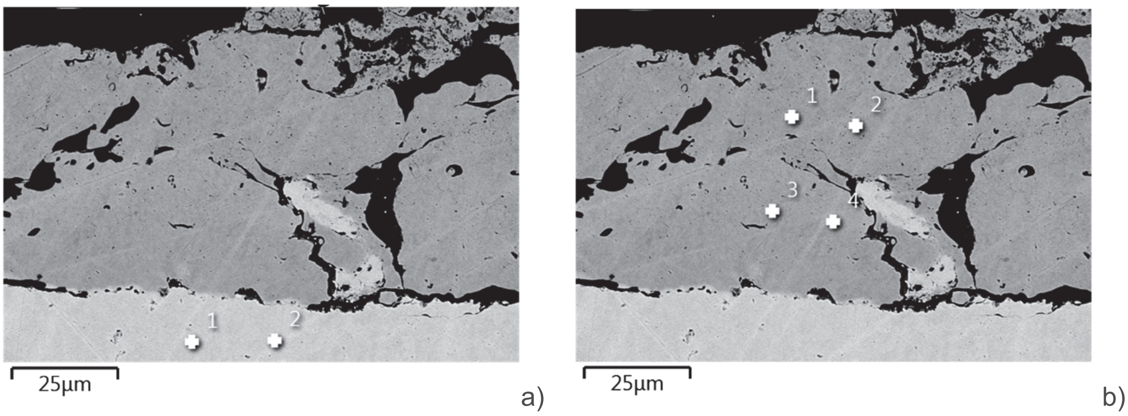

Figure 2 The specimen cross-sections SEM image for capacitor volume 150 µF with analysis of chemical composition in points

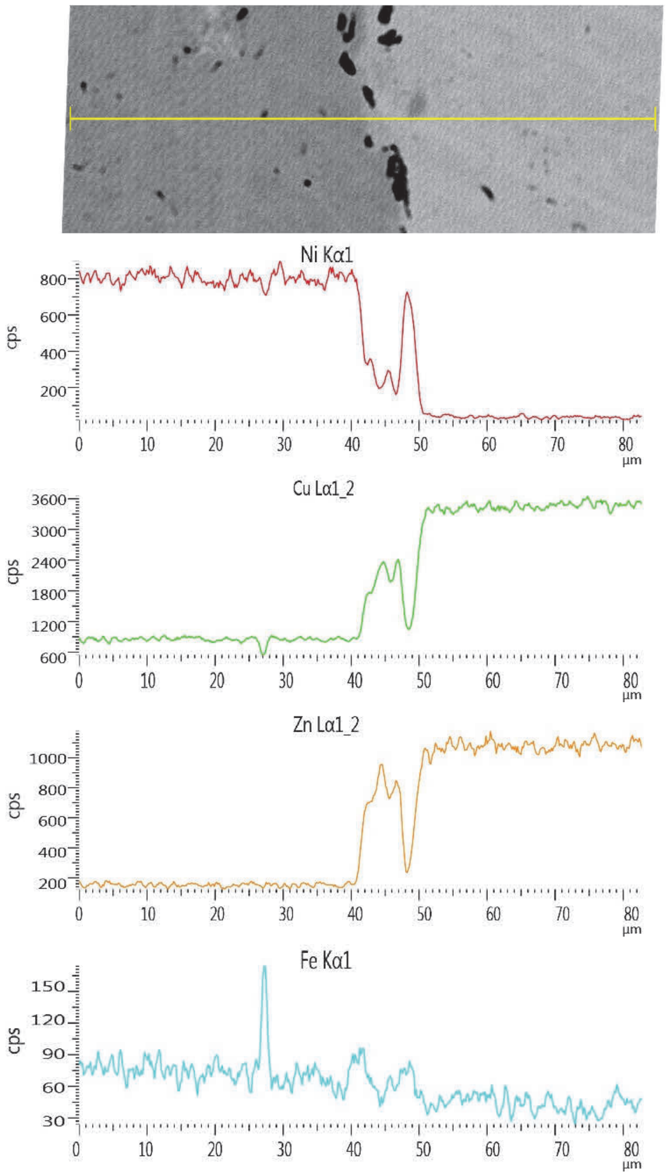

Figure 3 The specimen cross-sections SEM image and linear distribution elements in cross-section of 150 µF covered sample

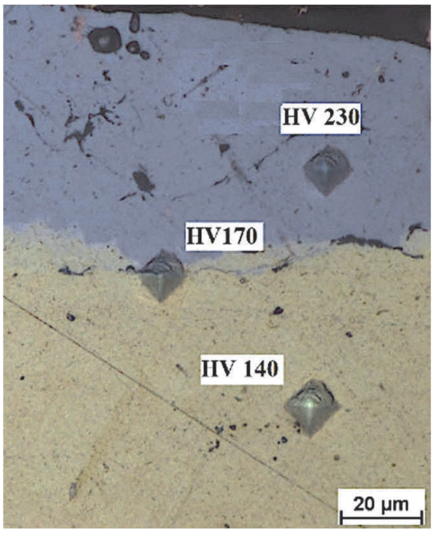

Figure 4 OM image of intender marks on BM, FZ and layer on samples 150 µF

4. CONCLUSIONS

In this study, the following conclusions were obtained, considering interesting properties of alloy 400 protective coatings covering CuZn30 by ESD method. An Alloy 400 coating layers having a thickness range 30 µm to 60 µm were formed on the surface of CuZn30 Bras substrate using ESD technique. The alloy 400 coatings include some microcracks lying throughout the coating from surface to interface which is nature of this process. The maximum cross-sectional hardness of the coatings was in the range of 230 HV. The bonding zone under the coating was formed by mixed materials of the electrode and the substrate. The coating makes metallurgical bonding to the substrate with an excellent bonding stability and intensity. The cooling rate in the ESD process is about 105 $K \cdot s^{-1}$ which is much higher than that in the conventional fusion welding processes. Because of the extreme cooling rate involved, there is no heavy elemental segregation in this process and this results in the prevention of formation of grain boundary terminal solidification constituents, which are the sources of liquation cracking. However, it seems important to provide enough energy in the application process that minimizes the tendency to crack and delaminate the layer being applied.

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