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COOPER-CARBIDE COMPOSITE LAYER OBTAINED BY LASER BEAM REMELTING

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Abstract: *The paper presents some investigations about the characteristics of composite layers deposited by laser beam remelting on a copper sample. The solution proposed is the development of new electrodes for spot welding reinforced using laser beam remelting and carbides embedding, that are not toxic for people or for the environment, since they do not contain metallic elements such as Cr, Be, Zr. The additional powder material, consisting of WC, was embedded into the copper sample surface, using different parameters values for the Nd:YAG laser remelting process. The structural characteristics and geometric thickness of the melted zone were measured in order to establish a correlation between the penetration and the tungsten carbide distribution for different values of the welding parameters.*
Key words: *laser, remelting, composite layers, electrodes*

1. INTRODUCTION

Copper and its alloys are widely used for industrial applications due to their excellent electrical and thermal conductivity, outstanding corrosion resistance, ease of fabrication, and good strength and fatigue resistance [Klimpel, 2007]. The reflectivity of cooper for the 1064 nm wavelength is over 90%. Therefore, in order to overcome this initial high reflectivity a large amount of power density is required. Once the laser is coupled and the material becomes molten the reflectivity drops significantly.

One of the cooper's application, the electrodes for spot welding, are often subjected to wear, plastic deformation, heating, material shredding [Scotchmer, 2006; Chen, 2005]. In order to increase the electrodes' durability, the main methods proposed to create the thin composite layers can be the pulverization of molten metal in which ceramic particles are embedded, surfacing with band electrodes which have a carbide composite core using the induction effect as a thermal source, depositing of thin strips obtained through ultra-rapid solidifying (rolls used for seam welding), depositing of a Cu-WC alloy composite layer using LASER beams [Zou, 2009]. Nowadays, the electrodes used for spot and seam welding are made from rolled profiles (round or plate), thermally treated, from Cu-Cr-Zn or Cu-Cr-Be alloys, metal cuts. In this case, the material usage coefficients are only 40 %. Another possible solution is to fabricate electrodes that have active areas made from Cu-CW sintered tips, brazed with silver alloys on Cu-Cr-Zr or Cu-Cr-Be alloys support. The disadvantages of this technological solution are the silver consumption and the limited working temperatures (600 – 800^{o}C) [Delavet, 2009]. Electrode's wear adversely affects the cost and productivity of automotive assembly welding due to reduced weld quality, reliability, and robustness. This implies increased inspection rates and greater control of welding parameters. Consequently, large potential cost savings and quality improvements are expected from substantial improvements in the electrode's life [Delavet, 2009]. The solution proposed in this paper is the development of new spot welding electrodes (for spot welding) reinforced using laser beam remelting and carbides embedding, that are not toxic for people and the environment, since they do not contain metallic elements such as Cr, Be, Zr. Their use allows a productivity enhancement at welding, due to the reduction of the equipment downtime.
The limitation of the method is the fact that the specular characteristic of the cooper surface determine a low value of the laser energy absorption on the surface.

2. EXPERIMENTAL DETAILS

2.1 Materials

The aim of the research theme was the realization on the top of the electrode for spot welding as a composite material, in order to ensure an improved resistance to deformation and a good conductibility of high intensity current without loses and excessive local heating. To achieve the composite layer, on the surface of the cooper samples there were milled 500µm deep grooves, then tungsten carbide powder (WC) with an average grain size of 13 microns has been placed into the grooves.

The second solution consisted of realizing a layer of pre-placed carbide and copper powder mixture on the copper smooth surface and then laser beam remelting (PCL sample). Before carbide deposition, the copper surfaces were cleaned using pure propane

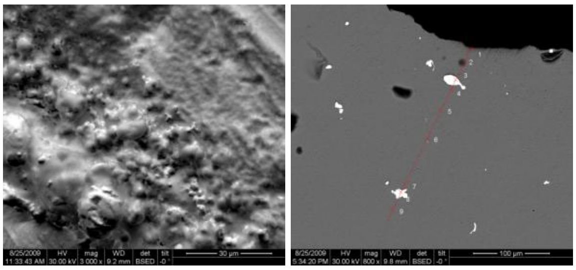
2.2 Parameters

The laser remelting parameters used for obtaining the composite layers are: pulse time 3ms, pulse frequency 2Hz. In order to obtain the extended remelting area, the focal spot value has been increased successively from 7 to 20 mm (P1 - 7mm, P2 - 15mm, P3 - 20mm).

Each of the melted zones of the sample was successively remelted by another superficial laser remelting process, using the same parameters value. For the PCL sample, a thin copper foil has been used to cover the welded surface in order to avoid the sputtering effects.

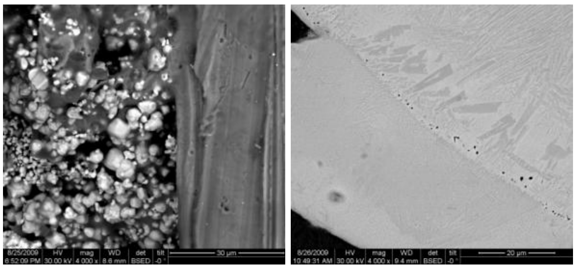
3. RESULTS AND DISCUSSION

After laser remelting, the samples were cut-off using a diamond disc, and then were prepared for SEM and optical analysis (by means of mechanical polishing and chemical etching). For each remelted zone, the average penetration was measured (P1= 527 µm, P2: 590 µm, P3: 616 µm, PCL: 105 µm) and the cross section was examined with different magnifications, in order to analyze the structure of the mixed zones and the carbide distribution. For a low value of the focal spot (7mm, sample P1) it is found that a fragmentation effect of carbides and mechanical mixing with copper matrix, takes place at a moderate amount of penetration (about 527microns) (Fig. 1).By increasing the value of focal spot to 15 mm (sample P2), the tendency is to constitute tungsten rich formations, having a coherent interface with the metallic matrix and a cellular growth appearance during solidification (fig. 2).



a) b)

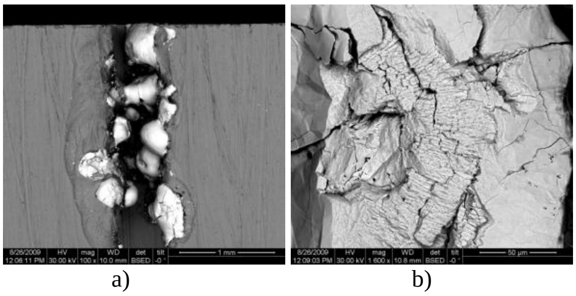
Fig.1. The carbide distribution for sample P1: a) Carbide's embedding effect (3000X),b) Carbide's distribution (800X)



a) b)

Fig.2. The carbide distribution for sample P2: a) Carbide's distribution (4000X), b) Cellular growth appearance into the carbide rich particle during solidification (4000X)

With the increasing of the focal spot value to 20mm (sample P3) there is an increase in penetration of the remelted zone and an extension of the dilution effect. Also, there is a trend of fragmentation of tungsten rich particles (Fig. 3). Using the high values of the laser remelting parameters it is found that the fine carbide powder tends to melt and form some tungsten rich, highly conglomerated components characterized by high microhardness values (average value of 1728 HV0.1 for melted carbides from samples P1-P3 and 1351 HV0.1 for fragmented carbides from sample PCL). Due to the fact that the cooper matrix which surrounds the carbides remains softer than the unmelted material, it is necessary to add some alloying elements into the mixed powder which allow improving both the microhardness and the interface between the carbide and the copper matrix. The resistance to the melting effect of the carbide in this case appears to be due both the large dimension (90 – 150 μm) and to the obtaining method (mechanical grinding). In the case PCL sample, the melting effects of the mixed carbide layer were reduced by the presence of one thin copper foil added above. In this case, the carbide particles were pushed and embedded into the copper surface without any dissolution effects (fig. 4). In order to estimate the dilution phenomena, a chemical analysis along the mixed zones has been done using EDAX ZAF quantification technique. Analyzing the values of major elements (Cu, C, and W) of the laser remelted areas it was found that the tungsten dilution into the copper matrix is insignificant due to the high cooling velocity.



a) b)

Fig.3. The overview of the remelted zone of sample P3: a) Conglomerates (100X), b) Carbide's fragmentation (1600x)

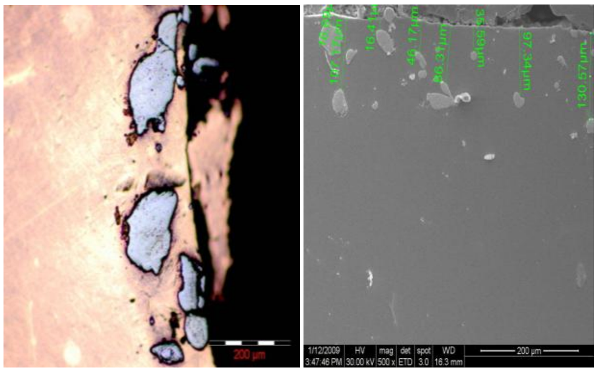


Fig.4. The overview of the remelted zone of sample PCL, 200X

4. CONCLUSION

Nd:YAG Laser beam remelting allows the obtaining of composite layers by tungsten carbide embedding into the cooper matrix, applying a series of successive passes. If the average size of the carbide powder is sufficient low, less than 5 μm, the carbide particles form very hard conglomerates which can enhance the wear resistance of the electrode's copper top.

Due to the fragmentation during solidification of this conglomerate it is necessary to add into the mixed metallic powder some elements like Cr, Ti and Ag which enhances the carbide's wettability and the microhardness of the surrounding matrix. The extension of the dilution phenomena is limited to about 50μm, depending on the values of the welding heat input and the sample's preheating temperature.

The penetration depth of the carbides into the composite layer obtained by laser beam remelting was between 290-616μm, thus the mechanical and wear resistance can be improved using this method.

The further research will be carried out for improving the composition of the hard powder (by adding Al, Fe and Cr) and for optimizing the parameters value of laser processing in order to achieve the increasing of microhardness of the composite layer.

5. ACKNOWLEDGEMENTS

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