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ISSN 0543-5846
METABK 56(3-4) 412-414 (2017)
UDC – UDK 621.793:621.9.015:662.75:620.18:620.17=111

SELECTED PROPERTIES OF HIGH VELOCITY OXY LIQUID FUEL (HVOLF) - SPRAYED NANOCRYSTALLINE WC-CO INFRALLOY™ S7412 COATINGS MODIFIED BY HIGH ENERGY ELECTRIC PULSE

Received – Prispjelo: 2016-12-31
Accepted – Prihvaćeno: 2017-04-14
Preliminary Note – Prethodno priopćenje

The paper presents a brief study of selected properties of HVOLF-sprayed nanocrystalline WC-Co Infralloy™ S7412 coatings modified by the application of a high energy electric pulse. The anti-wear coatings were applied on carbon steel with the use of High Velocity Oxy Liquid Fuel (HVOLF) spraying system TAFA – JP-5000. The process was modified by the application of the SST France & Vision Lasertechnik device WS 7000 S. The resultant type of coatings may be applied to increase the abrasive wear resistance of tools and machine parts. The properties of the powders and coatings were studied using metallographic methods and EDS analyses. The microhardness and nanohardness of the resultant layers were measured and Young's modulus of elasticity was determined.

Key words: coatings, surface layer modification, HVOF, metallographic methods, mechanical properties

INTRODUCTION

Machine components which need to withstand severe operating conditions, including friction, erosive wear, corrosion, etc., should be made of or coated with alloy materials [1, 2] that exhibit good surface properties such as high hardness or appropriate texture. Obtaining coatings whose thickness starts with several tens of μm and the introduction of the alloying elements enhancing the hardness, resistance to wear, corrosion, etc., such as tungsten (W), tungsten carbide (WC), molybdenum (Mo), vanadium (V), chromium (Cr), nickel (Ni) and others is of special interest in surface layer engineering. Such layers can currently be obtained by the application of the following techniques [2-10]:

- Facing by welding,
- Laser alloying,
- Electrical discharge alloying.

EXPERIMENTAL PROCEDURE

The feedstock powder coating was sprayed by means of HVOF gun systems, using kerosene (liquid fuel) HVOLF. The scheme is shown in Figure 1, kerosene and oxygen are burnt in the combustion chamber. The hot gas passes through the converging-diverging throat and along the 200 mm barrel before emerging as a free jet. The powder is injected downstream of the throat [2-5].

The SST France & Vision Lasertechnik microwelding device WS 7000 S was used as an electrical discharger. This welding machine generates pulses with an average frequency of 5 000 Hz. The welding time ranges from 0,1 ms to 99 ms with increments of 1,5 or 10 ms. The value of the generated welding-current reaches 11 900 A at the voltage of +/- 5 V. The device allows for the use of silver-tungsten-non-magnetic electrodes with the diameter of 5 mm. The high power pulse applied at one point melts the metal in a split second while allowing for cooling of the distal portion. The pulse microwelder is a great alternative to expensive laser equipment in industries such as prosthetics, jewellery and many others [11-13].

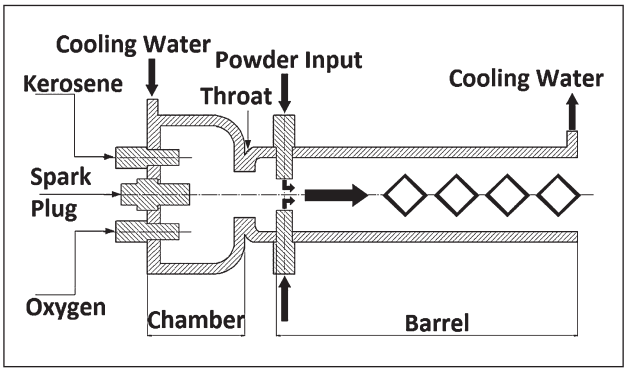

Figure 1 Scheme of HVOLF (High Velocity Oxy Liquid Fuel) system TAFA –JP-5000.

Microwelding device is often used for reparation and regeneration of foundry molds, as a joining technique in jewellery and electronics industry, and even in aerospace. Microwelding is also applicable in the case of very precise, small dimension welds. Therefore, this technique is used when the small size of the deposition areas prevents the conventional welding techniques from being applied [14-20].

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RESULTS AND DISCUSSION

Illustrating the fusion structures involved the use of the optical microscopy and the SEM (Scanning Electron Microscope) methods. The Nikon MA 200 Eclipse microscope with the image analysis system NIS 4.20 was used for metallographic specimens testing. All the samples were mounted in the vacuum with the use of Buehler EpoThin resin in order to protect the porous structure during the process of preparation. SEM examination was performed using a JEOL JSM 7100F microscope (with field emission - Schottky) equipped with Energy Dispersive Spectroscopy (EDS) OXFORD XMAX microprobe. A quantitative analysis of the sample SE microstructure was conducted to determine its porosity. It was necessary to determine the number of pores per unit analyzing the polished surface for different cross-sections. 5 areas – the Regions of Interests (ROIs) of the structure were analyzed. The Figure 2 shows an image of the morphology of powder INFRALLOY™ S7412.

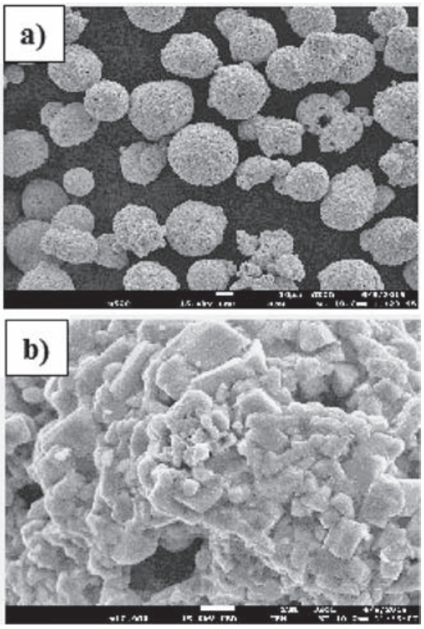

Figure 2 a) Powder morphology - visibly agglomerated particles, mag. 500 x , b) SEM photography of the powder surface, mag. 5 000 x

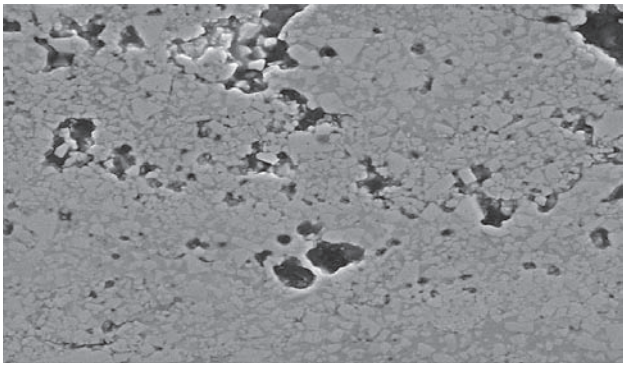

Figure 3 SEM photography of the surface layer (reveals porosity), mag. 5 000 x

The porosity was studied using an NIS 4.20 image analyser. Figure 3 shows an image of the porous structure of the sample.

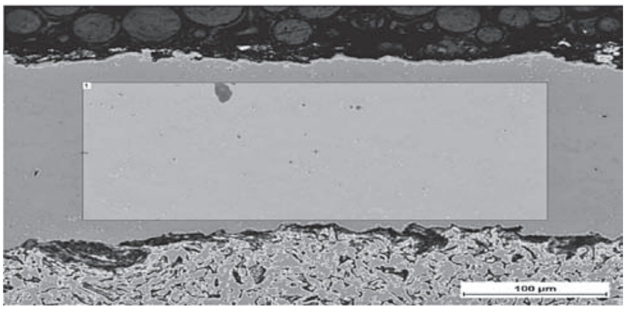

Figure 4 Microphotography of the sample cross-section with “ROIs” marked in the analyzed area.

Figure 5 shows the crossections of the WC-Co layer after a low energy or a high energy electrical discharge.

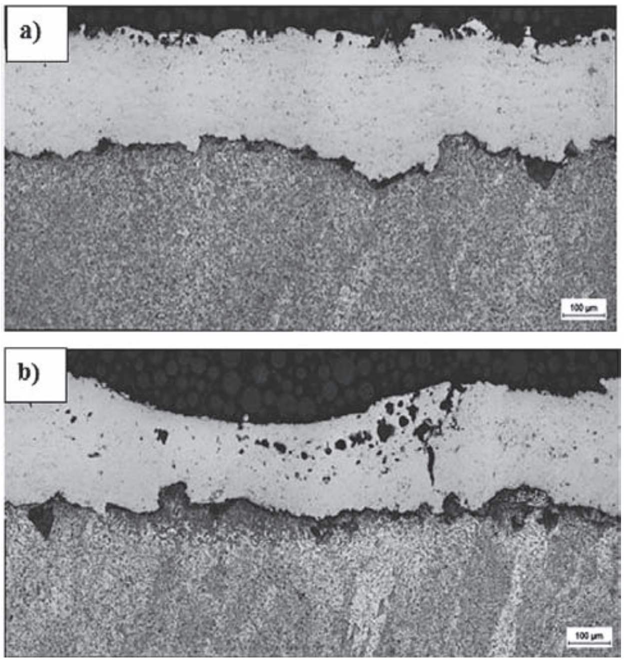

Figure 5 WC-Co layer cross-section after electrical discharge a) low energy pulse b) high energy pulse - 10 kW

Table 1 **Average nanointendation values**

	Max Load	Max Depth	Hardness /GPa	Hardness /HV	Elastic Modulus / GPa	Martens
Average value	100,33	711,06	13,12	1239,67	171,14	7,54

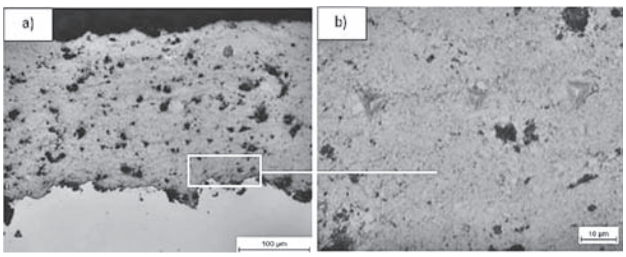

Figure 6 Nano-hardness distribution in the layer a) mag. x 200, b) mag. x 500

The Nanovea measurement instrument was applied for nano measurements of the spray layer material, whereas nanohardness tests were conducted by using a Berkowitz indenter, with an applied load of 100 mN.

Figure 6. shows the sample imprints of indenter.

SUMMARY

Based on the analysis of the study results it can be stated that:

- Nanostructured coatings show a more even distribution of WC particles in the matrix
- Nanostructural coating contains particles with regular round shapes in its structure. This is due to a higher effect of temperature in the spraying process owing to a much higher ratio of the surface area to the mass of particles
- The properties such as hardness and porosity of the nanostructured coatings are not satisfactory
- Using appropriate parameters of electrical pulse discharges makes it possible to improve the coating layer quality
- The results of the experiments show that it is possible to decrease the porosity of the nanostructural coating layer
- Exceedingly high electric pulse discharges cause noticeable, significant losses in the coating
- On the basis of 10 measurements it was found that the average nanohardness amounts to 1 239 HV
- Macroscopic and microscopic observations provide insight into the morphology of the structure

Compared to other technologies or solutions reported in the relevant literature it has been demonstrated that the applied technology leads to decreased porosity of the coating layer.

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Note: The professional translator for the English language is Dorota Pliżga, MA, Kielce, Poland.