PROPERTIES OF TITANIUM POWDER COATINGS DEPOSITED ON A SUBSTRATE OF STEEL-1030

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ABSTRACT

Composite coatings of titanium powder were deposited on steel-1030 samples by using the cumulative-detonation equipment. The dense layer from lamellas and deformed titanium particles is formed on the sample surface. A mean of lamellas hardness is 1500 $HV_{0,01}$. Scratch-test has shown that the coating has the high adhesive strength.

Key words: the cumulative-detonation technology, nanocomposite, lamellas, hardness, adhesive strength

INTRODUCTION

In view of high physical-mechanical properties of titanium and its compounds, it is of interest to deposit a coating of titanium-base composite materials on steel. At present, coatings of titanium powder obtained using a modernized HVOF [1], using the technology of cold coating [2] and the use of plasma generators and wires. A new energy-efficient design of cumulative-detonation devices for deposition of coating of titanium was used. This provides the formation of coating of high-quality at a lower cost of electricity in 20 times and the components of the combustible gas mixture of 5 - 6 times than the known HVOF devices [3]. The purpose of this study is to develop a power-saving technology and equipment for deposition of protective titanium powder coatings on surfaces of steel parts. The main problem is to provide a high adhesion of thin coatings to the steel substrate.

METHODS OF SAMPLE MANUFACTURING AND ANALYSIS

Specimens of steel-1030 consisting of Fe as a base, 0.3% C and 0.7% Mn were used as a substrate. Coating was deposited on the specimen surface by the cumulative-detonation device. Productivity 0.5÷1 kg/hour, gas mixture consumption ($C_3H_8+O_2$) – 2.84 m^3/hour, frequency – 20 Hz, distance to surface – 30 mm, coating thickness ~ 100÷150 μm. It is used titanium powder (Raymor Industries Inc.) with fraction 50 μm and the powder consisted of 100 wt. % Ti (*Fig. 1*).

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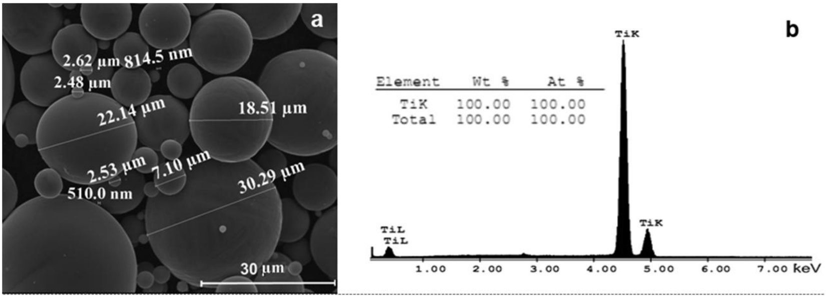


Fig. 1 – (a) Morphology and (b) elemental composition (energy dispersive spectrum) of titanium powder (SEM)

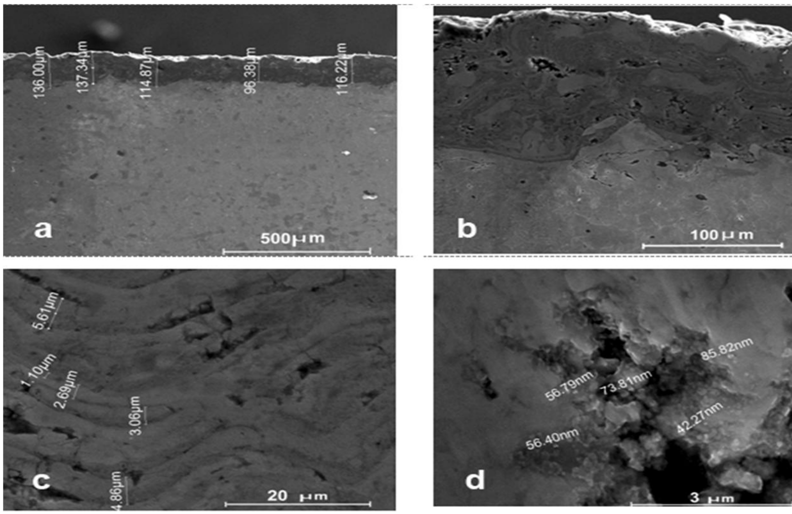
Morphological and compositional characterization of titanium powder and coating surface were performed using electron ion microscope Quanta 200 3D equipped with integrated microanalysis system Pegasus 2000 (SEM-EDS).

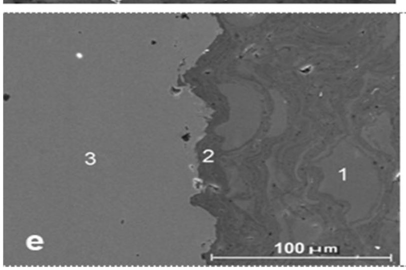
The Vickers hardness was measured by means of a microhardness tester under loads of 10-50 g. Adhesive, cohesive strength and the mechanism of coating destruction are defined by the scratch-tester REVETEST (CSM Instruments). Coating was deformed by a spherical diamond indenter of the "Rockwell C" type with a rounding radius of 200 μm at a continuously growing load in a range of 0.9-200 N. Results of the element analysis and defects in the deformed coating were studied.

RESULTS AND DISCUSSION

The coating (0.1-0.2 mm thickness) is uniform, dense, with a good adhesion to the substrate (*Fig. 3a*). A thickness of lamellas in the coating is 2÷3 μm. Pore size is similar. Apparently, the pores are formed during hot pressing of titanium powder. The study of morphology of the coating-substrate boundary is established that the visible boundary has no defects and fixed penetration of the coating to the substrate (*Fig. 3b, e*). High-speed deformation of dispersed particles of titanium leads to fragmentation of them into smaller particles with characteristic sizes smaller than 146 nm (*Fig. 3c, d*). It was established that all the coating consists of nano-dispersed fragments of titanium and titanium compounds with nitrogen, oxygen and carbon. Results of the analysis confirm the presence of the substrate material and coating in the transition area.

Results of hardness measurements are also indirect evidence of the interpenetration of the substrate material in the coating. The hardness of the border area of coverage is 3-4 times higher than the hardness of the substrate material and coating it was found. Hardness of thin lamellas in the coating is 1500 $HV_{0,01}$, which corresponds to the hardness of the intermetallic "titanium-iron" (*Fig. 4*).





Point	At.%			
	Ti	**Fe**	**O**	**W**
1	99.43	0.57	-	-
2	53.65	8.76	37.32	0.27
3	-	100.00	-	-

Fig. 3 – Morphology (a-d) and elemental composition (e) of titanium coating (SEM)

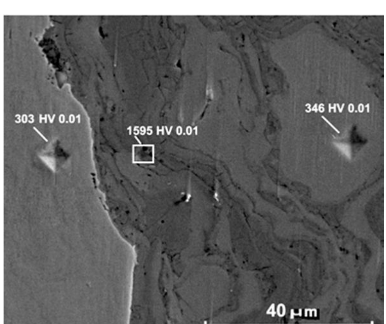


Fig. 4 – The microstructure of the surface of the transverse sections of the titanium coating on steel with hardness measurement points

In this study, adhesive strength was determined by critical load of L_C, which led to the destruction of the coating and the changing curves of the coefficient of friction and acoustic emission of the load (*Fig. 5*), optical microscope and SEM (*Fig. 5b*). Figure 5 shows that with the increase of the load cover is pressed into the substrate material (stage IV), which is accompanied by multiple chevron (transverse) cracks in the bottom of scratches and heavy cohesive failure of the material that forms the border sintering (*Fig. 5a*). However, the elemental analysis of a trace of deformation was showed that at the maximum possible load on scratch-tester about 190 N was not a delamination of coating. Elemental analysis of traces of deformation of the diamond indenter showed the same content of titanium and iron in the deformed parts of the coating and the coating (*Fig. 5b*).

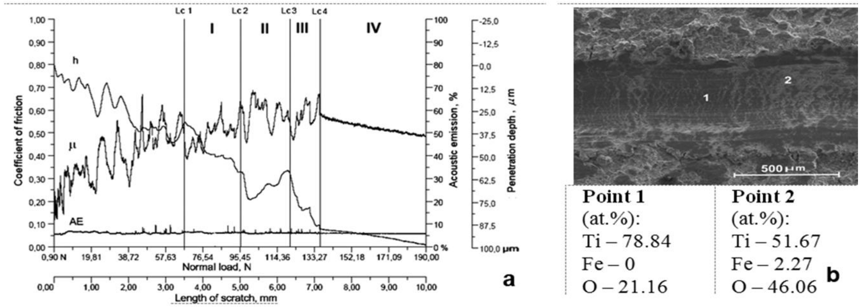


Fig. 5 – Results of adhesion tests (a). Morphology and elemental composition (b) of system of “coating – substrate” at the point of contact with indenter

CONCLUSIONS

The cumulative-detonation technology and equipment is created for deposition of nanocomposite titanium powder coatings on the steel samples. The gas mixture consumption (propane-oxygen-air) is up to 6.3 m^3 per 1 kg of powder. The dense layer from lamellas and deformed titanium particles is formed on the sample surface. The technology provides high quality face-boundary between coating and substrate due to the interpenetration of the materials. Formed coating has high adhesive and cohesive strength, density and the presence of nanosized structures.

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