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RESEARCH ON INFLUENCE OF IMPURITY OF NANOPOWDER OXIDE ALUMINIUM ON WEAR RESISTANCE OF PLASMA COATINGS

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Abstract: *Introduction of nanocomponents to the matrix is considered as one of the effective methods to control structure and increase operational properties of sprayed coatings. Wear resistance, microhardness and resistance to the thermocycling of plasma coatings on the basis of self – fluxing powder of Metco 14E from addition to its composition of nanodisperse powder of aluminum oxide was investigated. It is established that addition of nanodispersed aluminum oxide in composition of the self-fluxed powder of the Metco 14E brand is resulted in increase of wear resistance and microhardness plasma-sprayed coatings.*

Keywords: *plasma-sprayed coating, thermal cycling, nanosized powders, microstructure.*

1. INTRODUCTION

Plasma protective coatings are one of the effective methods to increase reliability and durability of details and knots of modern equipment, which works in the conditions of high loadings, dry, and limit friction, a gas erosion and abrasive wear. The special place among them is taken by coatings which provide a high level of wear resistance. As a result of the heavy loading modes, mechanisms details often fail through wear of working surfaces. Therefore, there is an urgent need for increase of firmness of surface layer.

In recent years researches by many scientists established that one of major factors, which influence a structure and properties of the surface layers, is an introduction to their composition of impurity in the form of different nanodisperse powders of carbides, borid, oxides and nitrides of transitional metals (Kulik et al., 1985, Borisov et al., 2010 and Chornyi et al., 2015). The particles of nanopowders, as modifiers of the first-kind, provide the accelerated and more uniform hardening of metal in a coating, carry out a certain influence on the size of grains and nonmetallic inclusions. Therefore, test results of wear of weld metal type X39Cr13, X25GS2 modified by nanooxides of aluminum, titan and silicon through the weld pool according to different schemes of introduction are given in work (Kuznetsov et al., 2015). It is shown that introduction to a weld pool of nanooxides leads to noticeable increase of wear resistance of the weld metal by 5 - 7 times whereas with conventional approaches based on the alloying system changes only by 1.5 - 3.0 times.

Possibility of modification of a layer of bronze in the process of plasma powder surfacing of material Metco 445 by nanoparticles of Al_2O_3 is shown in work (Knjaz'kov et al., 2012). Change of the structure of bronze and substantial increase of hardness of the deposited layer is a result of introduction of nanoscale components.

The work (Derlugjan et al., 2013) is devoted to search of effective modifiers for receiving composite coatings with antifrictional properties. In mentioned work after the analysis of efficiency of use of ultrafine oxides with structure of corundum and rutile, carbon and boron nitride, metals with structures like tungsten-type and magnesium the conclusion about application of aluminum oxide as modifier was made. In work (Mazaheri et al., 2013) by means of a high-energy planetary ball mill, it was received the nanocomposite powder Al - Al_2O_3 with a particles size of aluminum oxide of 20 nm - 40 nm that provided increase of hardness by 1.5 - 2.0 times and wear resistances of the spray coatings on average for 85% - 91%.

Therefore, introduction of nanoscale powders to a matrix allows to solve the set of engineering problem by creation of coatings with special properties on a surface of a detail or a product. It becomes possible a production of details from cheaper materials or with the smaller thickness of a wall, without use of expensive and rare materials, at the same time even rather small increase of wear resistance of such details gives considerable economic effect.

The purpose of work consisted in research of wear resistance of plasma coatings on the basis of the self-fluxing powder Metco 14E of the system Ni-Cr-B-Si with addition to its composition of nanosized powder of aluminum oxide.

2. EXPERIMENTS' DETAILS

To determine the optimum values of nanocomponents contents in plasma coatings a test for wear resistance was carried out and determined their microhardness. Process of wear was examined in the conditions of dry friction by machine of friction according to the scheme a roller (a counterbody the tempered W1-7 steel) - flat specimen with a coating at loading of 3 kg. Microhardness of the received coatings was determined by Vikkers diamond pyramid indentation with load of 0.98 N on the microhardness tester TH715.

Oxide Al_2O_3 with fraction of 50 nm - 60 nm was used as nanocomponent which was entered in concentration from 0.5% vol. to 5% vol. Mechanochemical treatment in XQM-2 aplanetary ball mill with additional pumping out of working tanks was used for preparation of homogeneous powder mixture with micro- and nanoparticles. Aluminum oxide nanoparticles in the conditions of vacuum and mechanochemical processing pass into the activated state and join to particles of other elements, forming physical sheaves between components that allows to transfer during a further plasma spraying in a coating.

Powder spray was carried out using a plasma torch with partially taken out arc and additional blowing of a plasma stream a concentric stream of protective gas. Current of an arc was established within 80 A - 90 A, voltage of 35 V - 50 V, productivity to 4 kg/hour with the general expense of the plasma-forming, transporting and protective gas (argon) of 5 l/min. With these design features and the technological modes, character of a current of a plasma stream was close to laminar that provides favorable conditions for preservation and transferring to a coating of nanoparticles.

3. RESULTS

Use of nanodisperse powder of aluminum oxide in combination with particles of large fraction leads to formation inhomogeneous structure of a coating. In a powder particle which gets on a basis surface during a plasma spraying to speed no more than 200 m/s there are usual physical and chemical processes, however through existence of nanoparticles of a condition of formation of coatings change. Deformation of the spray particles is carried out at the reduced viscosity and density which can lead to reduction of the area of physical contact and deterioration in mechanical properties with increase in amount of nanopowder in a coating. During crystallization and cooling in a coating there can also be chemical reactions and polymorphic transformations under the influence of nanoparticles that leads to formation of difficult structure of a composite coating. The phase structure and properties which depends on reaction development, both in a plasma stream, and on a basis surface.

In order to create a homogeneous structure and increase of adhesive strength, specimens with plasma-sprayed coatings were a subject to melting in the muffle furnace at a temperature (1050 ± 20) °C for 5 min.

The chemical composition of the plasma sprayed coatings in certain areas, which was investigated by means of the microanalyzer REM 106Y, is given in Tab. (1 and 2) and in Fig. (1).

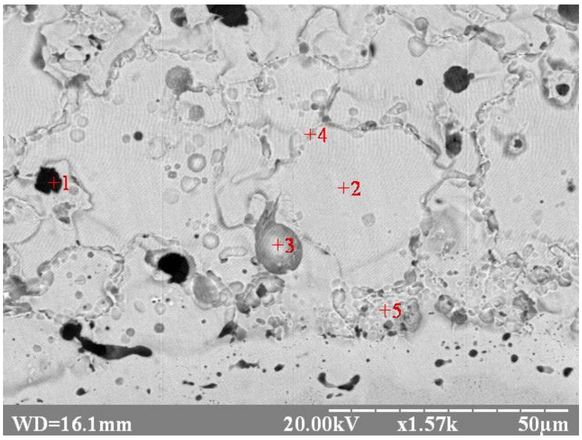


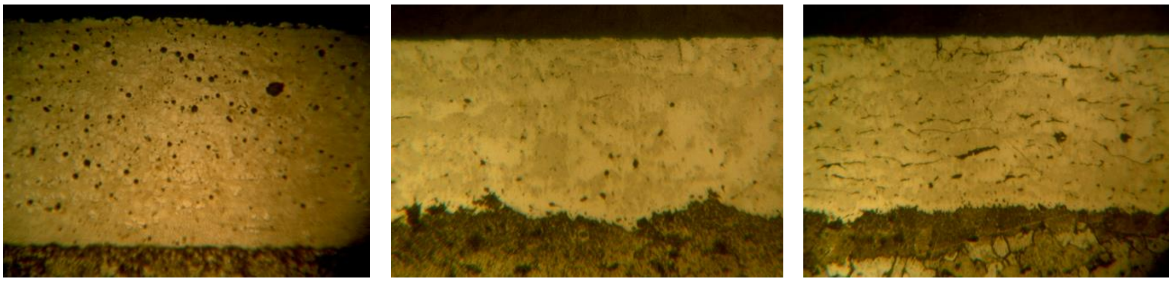
Figure 1: Microstructure of a plasma coating from powder Metco14E+0.2% Al_2O_3.

Table 1: Chemical composition of a plasma coating on the basis of the self – fluxed powder Metco14E+0.2% Al_2O_3.

Spectrum / Elements, %	1	2	3	4	5
Ni	73.73	86.75	87.00	84.16	80.63
Fe	4.57	3.77	3.69	4.84	7.17
Cr	19.61	8.38	9.12	10.17	11.25
Si	1.16	0.98	0.15	0.79	0.76
Al	0.93	0.13	0.05	0.04	0.19

The carried-out microstructural analysis of coatings (Fig. (2)) showed that the melting leads to additional ordering of a structures and increase of the adhesive durability characteristic of formation of transitional diffusive zones which are most visually observed at digestion in chloride anhydrite. Increase in a volume fraction of nanoparticles of Al_2O_3 to 5% leads to cracking of a covering as a result of increase in residual stresses.

Results of the microanalysis demonstrate uneven distribution of elements in structure of a coating, in particular aluminum, which is generally concentrated in not alloyed coating sections (spectrum 1 Fig. (1)). Based on these data it is possible to state about existence and distribution in a coating of nanodisperse particles of aluminum oxide.



(a) (b) (c)

Figure 2: Microstructure of a plasma coating system Metco 14E+Al_2O_3 after melting and digestion in the electrolytic way: (a) Metco 14E, (b) Metco 14E + 1% vol. of Al_2O_3, (c) Metco 14E + 5% vol. Al_2O_3.

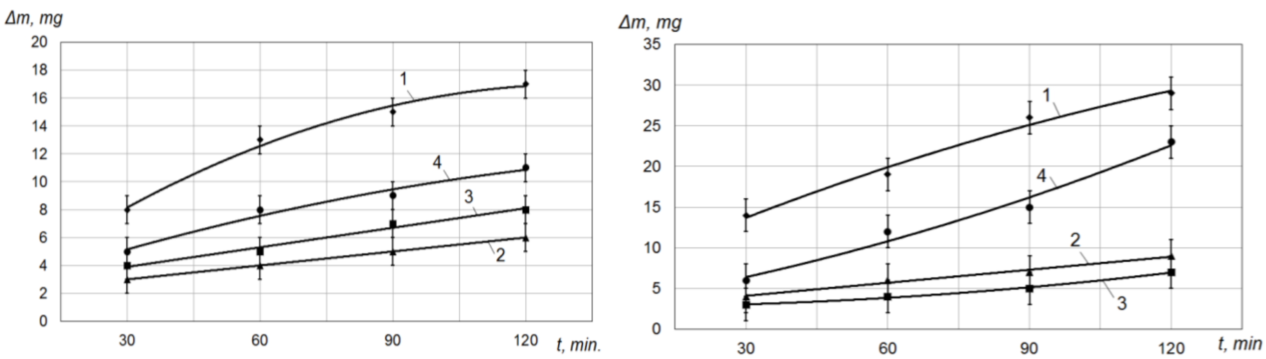
Coatings on the basis of the powder Metco14E gave in to test for firmness to thermocycling. Specimens with a coating heated up in the muffle furnace to temperature 850±20ºC then sharply cooled in water. Chemical composition of a surface coatings after X-ray fluorescent analysis shown in Tab. 2.

Table 2: Chemical composition of plasma coatings on basis of self-fluxed powder Metco 14E.

Coating \ Elements, %	Ni	Cr	Si	Fe	Al	Ca	Cu	P	S
Metco 14E (50 thermocycles)	72.237± 0.349	12.489± 0.149	7.242± 0.355	5.954± 0.089	–	0.995± 0.173	0.608± 0.070	0.475± 0.089	–
Metco14E +0.5%Al_2O_3 (50 thermocycles)	65.621± 0.564	15.531± 0.152	7.927± 0.407	5.779± 0.065	1.819± 0.700	1.672± 0.087	0.479± 0.029	0.775± 0.076	0.398± 0.117
Metco 14E +1%Al_2O_3 (50 thermocycles)	69.888± 0.525	14.510± 0.165	6.763± 0.339	5.973± 0.087	0.381± 0.591	1.424± 0.151	0.429± 0.053	0.197± 0.094	0.435± 0.098
Metco14E +1.5% Al_2O_3	73.240± 0.489	15.259± 0.154	2.804± 0.248	6.046± 0.082	1.110± 0.561	0.239± 0.106	0.259± 0.053	–	1.044± 0.115

As a result of the tests, we can conclude that all coatings withstood 50 thermal cycles without delamination. At the same time a coating without nanopowder impurity after the first 15 cycles had darkening, and after 50 cycles strongly oxidized and damaged surface. The microanalysis of a coating showed that aluminum oxide nanoadditives during spraying are transferred to the coating and do not burn out during temperature tests (Tab. (2)).

Tests for wear in conditions of dry friction (Fig. (3)) showed that the range of optimal values nanopowder content is in the range of 0.2 % - 1.0 % vol. at use of powder base on self-fluxed alloy system Ni - Cr-B-Si (Metco14E).



(a) (b)

Figure 3: Kinetics of wear not melted off (a) and melted off (b) plasma coatings: 1 - coating Metco14E; 2 - coating Metco14E +0.2%vol.Al_2O_3; 3 - coating Metco14E +1%vol.Al_2O_3; 4 - coating Metco14E + 5%vol.Al_2O_3.

Results of measurement of microhardness and relative wear resistance of plasma coatings on the basis of the powder Metco14E with nanoadditives of Al_2O_3 are presented in Tab. 3.

Table 3: Microhardness and relative wear resistance of coatings.

Coating	Microhardness, GPa	Relative wear resistance, %
Metco14E	3.4	1.0
Metco14E +0.2% Al_2O_3	4.8	6.0
Metco14E +1% Al_2O_3	5.2	2.5
Metco14E +1.5% Al_2O_3	4.4	-
Metco14E +5% Al_2O_3	4.8	-

Dependence of microhardness of the raised dust layers on increase in concentration of nanodimensional particles - it is not revealed (Tab. (3)). The maximum value of microhardness is established at addition 1 vol. % nanopowder Al_2O_3, also represents 5.2 GPa. The best relative wear resistance of 5-6% at 0.2% of Al_2O_3 of nanopowder.

4. CONCLUSION

It is established that optimum value of introduction of nanodisperse aluminum oxide to a composition of self-fluxed powder of the Metco14E brand in the range of 0.2 % - 1 % volume destinies. At the same time, microhardness for 25 % - 40 % grows and there is an increase of wear resistance of the raised dust plasma coatings by 2.5 - 3 times.

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