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INVESTIGATION OF COATINGS OBTAINED BY VACUUM-ARC DEPOSITION

Abstract. The paper presents the results of the application of the vacuum-arc spraying method to obtain coatings on the structural material. Experiments were carried out on the vacuum-arc accelerator VAA-1. The processing parameters were selected in order to achieve the most effective result. The structure and physical and mechanical properties of the surface layer of stainless steel after deposition of copper coatings have been studied by means of x-ray spectral analysis, scanning electron microscopy and metallography. The presented results are an intermediate stage in a series of experiments to obtain coatings by this method. It is established that there is a decrease in the microhardness of the surface layer due to the formation a coating of copper. There is also observed a sealing and smoothing of the surface of the test sample, which should lead to improved performance properties of the material. In addition, deposition by this method leads to good continuity and adhesion of the coating to the substrate.

Keywords: vacuum-arc, plasma spraying, copper coating, deposition, smoothing, microhardness.

Introduction

The actual problems of materials science include the development of technologies for improving surface properties of various structures and products. One of the solutions to the tasks may be coating by plasma spraying.

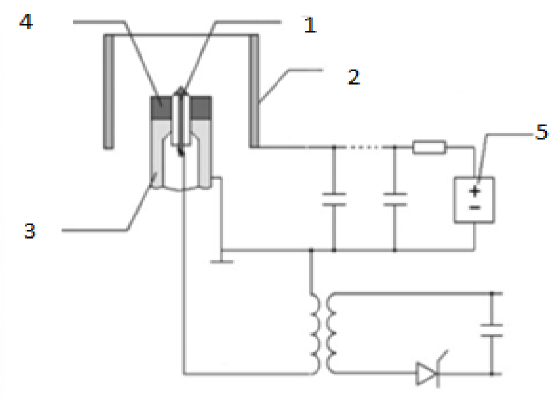
Plasma spraying is widely used in those branches of industry and technology where necessary to protect the machine parts and products from intensive wear, corrosion, erosion, cavitation, abrasion, heat, thermal shock [1]. Sputtering is performed in vacuum equipment of the type VAA-1. Vacuum-arc accelerators (VAA) are widely used to change the structure of materials and for surface treatment of metals and alloys. By applying a protective layer on the surface of materials using VAA can improve their chemical composition and physical properties [2].

Experimental setup

In this paper, experiments on the deposition were conducted on experimental installation VAA-1. The operation of pulsed vacuum-arc accelerator (VAA-1) is not different from that of classical coax, as in both cases; there is a coaxial anode and cathode. The difference is that in case of VAA, the plasma is formed as a flow with radially symmetric current distribution, constricted on the surface of the cathode and is ejected in the interelectrode space due to its own magnetic field. Figure 1 shows the electrical scheme and the appearance of the installationVAA-1.

The installation design provides for the possibility of both continuous and pulsed mode arc at a frequency of 0.5÷100 Hz.The vacuum system consists of forevacuum and diffusion pump, which provides the ultimate pressure in a vacuum of 10^{-6} Torr.The admission of the working gas (argon or nitrogen) is carried out using a needle leak valve with the possibility of regulating the gas pressure in the range from $1{,}3\times10^{-3}$Pato4×10^{-1}Pa. Electrode design is a complex system in which the spraying material is cathode.

Tests have shown stable operation of VAA when the voltage on the anode is above 50 V, and reaching the vacuum of $2\cdot10^{-3}$Torr.The operation of VAA has been tested at frequencies of 2, 10 and 25 Hz and found that at 50 Hz was achieved saturation [2].



a)

b)

a) 1- burning electrode, 2-cathode, 3-holder, 4-anode, 5-power supply

Figure 1 – Electrical installation scheme of VAA-1 (a), the appearance of the installation VAA-1 (b)

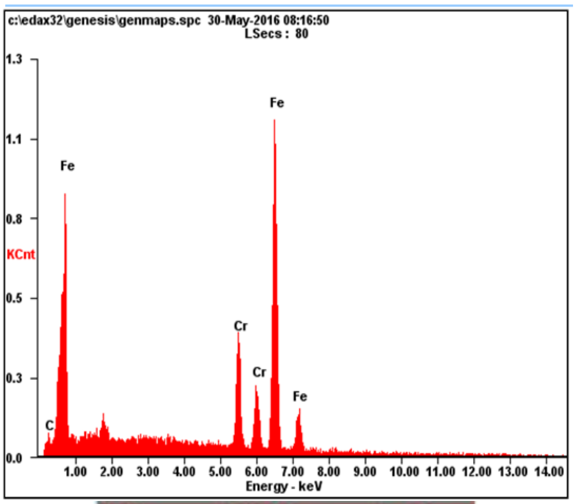
Experiment details.

In the experiment, the samples of the test material is loaded into the working chamber at a residual air pressure of 1,33×10^{-3} Pa(1×10^{-5}Torr).After the gas inflow, electric arc evaporator is powered and sets the arc mode. In order to initiate the arc discharge the evaporator design is provided an ignition electrode made of metal, situated in the shell of insulating material (ceramics), and located near the cathode. The ignition of the arc discharge is ensured by transmission of the ignition pulse with amplitude ~ 10 kV.The film on the cathode under the current action is evaporated and ionized in the area of ignition.Operation of the evaporator based on the erosive destruction of the surface layer of the cathode that provides stable combustion of a vacuum-arc discharge between the cathode and the anode [3]. In the experiment used pulsed mode of arc burning and the current load of the evaporator was regulated in steps from 5 to 75 A, where the arc voltage is not less than 20 V.The current density in the cathode spots reaches values of 10^6-10^7 A/cm^2, the energy power from 10^5 to 10^8 W/cm^2[4].

Results

The spray material is deposited on the surface of the stainless steel samples.The selected objects were subjected to all steps of pre-treatment of their surfaces [3,5] and were processed the same number of plasma pulses. The gas pressure in the working chamber was maintained about 10 Pa, the frequency of 5 Hz, the voltage of 470 V, the processing time of 40 min, the cathode is copper.To determine the range and efficiency of spraying samples of stainless steel were placed on a holder and processed simultaneously.

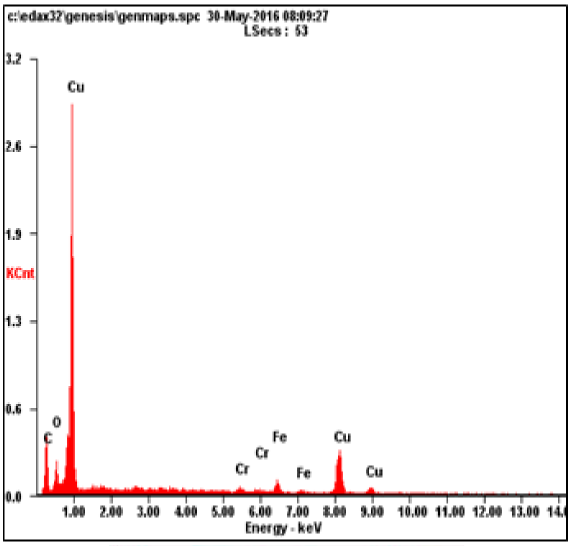
The chemical composition of the surface layer of material was determined by X-ray spectroscopy on Pegasus 2000 (figures 2, 3 and 4, respectively) of the samples before (№7) and after applying a copper coating (№1 and №3).



Element	Wt%	At%
CK	2.09	8.93
CrK	16.42	16.20
FeK	81.49	74.87
Matrix	Correction	ZAF

Figure 2– X-ray spectral analysis of the sample №7

X-ray spectral analysis was showed the efficiency of the spraying process, as so in chemical composition of the coating was found up to 71,47% copper (sample №1) and 92,56% (sample №3) respectively. The difference of the percentage content of copper in the samples is explained by the position of the samples on the holder.



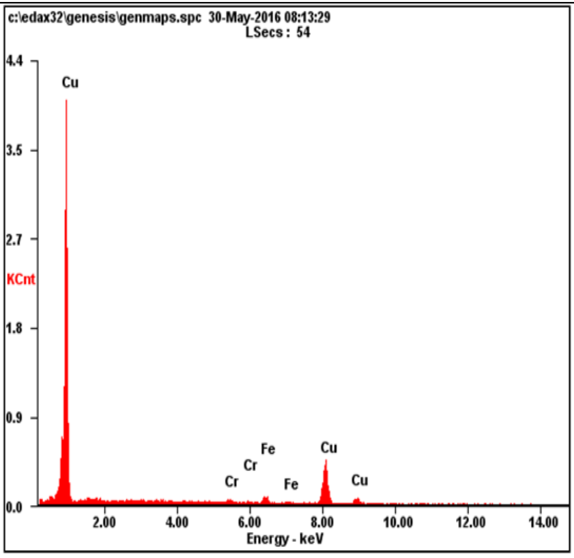
Element	*Wt%*	*At%*
CK	16.76	47.78
OK	4.21	9.00
CrK	1.67	1.10
FeK	5.89	3.61
CuK	71.47	38.51
Matrix	Correction	ZAF

Figure 3 – X-ray spectral analysis of the sample №1

During the experiment sample №3 was placed in the center, which increased the efficiency of the results. In addition, it was found the increase in carbon content from 2,09 to 16,76 % and a decrease in iron and chromium ~ 7 and 10 times, respectively, which is evidence of internal rearrangements of the structure.The carbon apparently comes from the residual air or as a result of erosion of Plexiglas, insulating the electrodes of the accelerator.

The surface morphology (figure 5) and the Vickers hardness of the copper coatings was studied using scanning electron microscopy (SEM) methods.

As can be seen from figure №5 the influence of plasma energy density above 22 J/cm^2 leads to a smoothing of the surface and increase the continuity of coating at submicron level.



Element	*Wt%*	*At%*
CrK	1.70	2.05
FeK	5.74	6.46
CuK	92.56	91.49
Matrix	Correction	ZAF

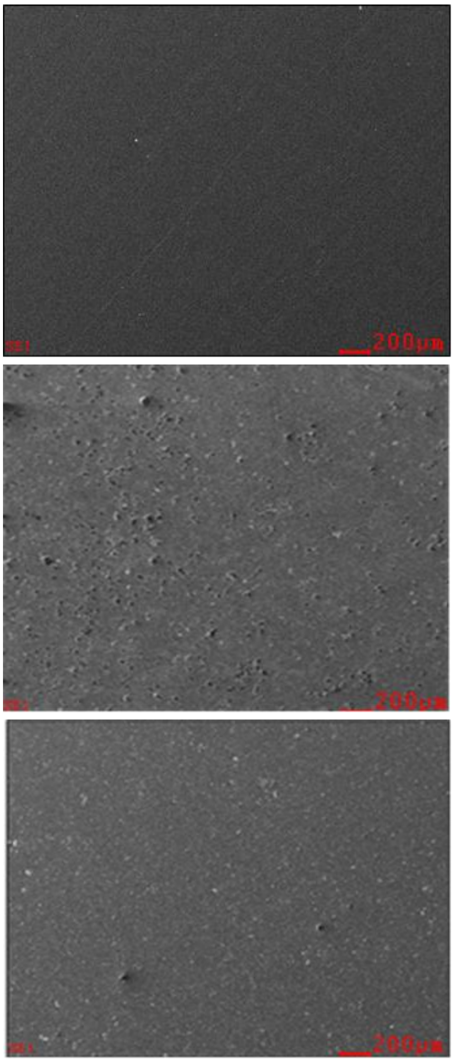
Figure 4 – X-ray spectral analysis of the sample №3

The results of microhardness measurements on metallographic inverted reflected light microscope "METAVAL", at F=300 N, t=10 s (table) show that copper plating the surface leads to its decrease, which agrees well with the analysis of the chemical composition. Copper is known to be a softer material than stainless steel substrate.

Table –The measurement results of microhardness of the samples

Sample	Microhardness, HV
№7	275,1
№1	255,3
№3	261,7

However, these readings of microhardness of the surface is somewhat higher than for the coaxial plasma accelerator CPA-30 received recently.



a) b) c)

Figure 5 –Surface microstructure of samples a)№7, b)№1 and c)№3

Conclusions. Currently, great prospects for development receive technology increases the durability of structural materials and products from them.Proposed in this paper the method for surface modification of metallic materials using equipment of the type VAA-1 allows to obtain metallic coatings on substrates of structural steel with high performance and requires low cost for production.

The change in the internal structure and properties of the surface during plasma treatment were investigated by x-ray spectral analysis and electron microscopy was showed the presence of copper (up to 71,47 % and 92,56%) and increase in carbon percentage 8 times, accompanied by decrease in iron and chromium ~ 7 and 10 times, respectively.This effect may be caused by structural rearrangements. The decrease in hardness of the surface layer shows the efficiency of the spraying process and the possibility of obtaining coatings with high adhesion and continuity.

The results of experimental studies can be applied in the development of vacuum technological installations and technologies for the improvement of physical-mechanical properties of materials.

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Keywords: vacuum-arc, plasma spraying,copper coating, deposition,smoothing, microhardness.

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ИССЛЕДОВАНИЕ ПОКРЫТИЙ, ПОЛУЧАЕМЫХ МЕТОДОМ ВАКУУМНО-ДУГОВОГО ОСАЖДЕНИЯ

Аннотация. Приведены результаты применения метода вакуумно-дугового напыления для получения покрытий на конструкционном материале. Эксперименты проводились на вакуумно-дуговом ускорителе ВДУ-1. Параметры обработки были подобраны с целью достижения максимально эффективного результата. С помощью методов рентгеноспектрального анализа, растровой электронной микроскопии и металлографии исследованы структура и физико-механические свойства поверхностного слоя нержавеющей стали после осаждения медных покрытий. Представленные результаты являются промежуточным этапом серии экспериментов по получению покрытий данным методом. Установлено, что происходит снижение микротвердости поверхностного слоя за счет образования покрытия меди. Наблюдается также уплотнение и сглаживание поверхности исследуемого образца, что должно приводить к улучшению эксплуатационных свойств материала. Кроме того, осаждение этим способом приводит к хорошей сплошности и адгезии покрытия с подложкой.

Ключевые слова: вакуумно-дуговой метод,плазменное напыление,медное покрытие, осаждение,сглаживание, микротвердость.

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ВАКУУМДЫ-ДОҒАЛЫҚ ӘДІСМЕНАЛЫНҒАН ТҰНДЫРЫЛҒАН ЖАБЫНДЫЛАРДЫ ЗЕРТТЕУ

Аннотация. Конструкциялық материалжабындыларыналуүшінвакуумды-доғалықтозаңдатудың әдісін қолданылған нәтижелерікелтірілген. Эксперименттер ВДҮ-1 вакуумды-доғалық үдеткіште жүргізілген. Өңдеу параметрлері максималды тиімді нәтижеге жету мақсатында таңдалынып алынған. Мыс жабындыны қондырғаннан кейінгі тот баспайтын болаттың беткі қабатының физика-механикалық қасиеттері рентгендік спектральды талдау, растрлы электронды микроскопия және металлография әдістерінің көмегімен зерттелген. Ұсынылған нәтижелер бұл әдіспен жабындыны алу бойынша

эксперименттер сериясының аралық кезеңі болып табылады. Мыс жабындының пайда болуына байланысты беткі қабатының микроқаттылығы төмендеп өзгергені анықталды. Сондай-ақ, зерттеліп отырған үлгінің беткі қабаты тығыздалғаны және тегістелгені байқалады, бұл материалды қасиеттерін жақсаруына әкелуі тиіс. Сонымен қатар, осы әдіс арқылы тұндыру жақсы тегістеуге және жабынды адгезиясы бар төсеніш алуға болады

Түйін сөздер: вакуумды-доғалық әдісі, плазмалық тозаңдау, мыс жабынды, тұндыру, тегістеу, микроқаттылық