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**ENVIRONMENTAL INNOVATIONS IN INDUSTRY<sup>1</sup>****Sayenko V., st. of gr. MC-51-21, KhNAHU**

**Abstract.** Object research - processes formation structures and properties teeth buckets excavators ion-plasma chroming. Property from ub iv buckets excavators changed applying ion-plasma coatings chromium nitride. This species is selected for protection from corrosion, wear, sticking to the surface contacts mater ials. In practice modern enterprises are applied causing chrome coatings to increase the service life teeth buckets excavators. Quality these coverage in does not meet the needs of modern production. There are many nowadays attention is provided application modern methods superficial processing for increasing wear resistance of parts of nodes that work in the conditions intensive wear and tear. Based on analysis literary data and experience modern we had enterprises - the ion-plasma method is chosen processing teeth buckets excavators, for increase their longevity. Causing coatings was carried out by the method of condensation in the conditions ionic bombing of the Bulat 3T installation. Was selected coating composition and optimal modes him causing. Received high hardness and wear resistance, low coefficient friction, good chemical stability what provided a high resource of researched details in any conditions operation.

**Keywords:** wear resistance, abrasive, welding , plasma, ladle, layer, corrosion, steel.

**ЕКОЛОГІЧНІ ІННОВАЦІЇ В ПРОМИСЛОВОСТІ****Саєнко В., ст. гр. МС-51-21, ХНАДУ**

**Анотація.** Об'єкт дослідження - процеси формування структури та властивості зубів ковшів екскаваторів іонно-плазмового хромування. Мета роботи: розробка технологічних основ застосування іонно-плазмового хромування для підвищення зносостійкості зубів ковшів екскаватора на основі управління параметрами структури та функціональними властивостями покриттів для забезпечення їх довговічності. Предмет дослідження - закономірності формування структур і властивостей поверхневих шарів зубів ковшів екскаваторів. Властивості зубів ковшів екскаваторів змінено нанесенням іонно-плазмових покриттів нітриду хрому. Цей вид обраний для захисту від корозії, зношування, налипання на поверхню контактів матеріалів. На практиці сучасних підприємств застосовуються нанесення хромованих покриттів для збільшення терміну служби зубів ковшів екскаваторів. Якість цих покриттів не відповідає потребам сучасного виробництва. В даний час багато уваги приділяється застосуванню сучасних методів поверхневої обробки для підвищення зносостійкості деталей вузлів, що працюють в умовах інтенсивного зношування. На основі аналізу літературних даних та досвіду сучасних нами підприємств обрано іонно-плазмовий метод обробки зубів ковшів екскаваторів, для підвищення їх довговічності. Нанесення покриттів проводилось методом конденсації в умовах іонного бомбардування установки Булат 3Т. Підібрано склад покриття та оптимальні режими його нанесення. Отримана висока твердість і зносостійкість, низький коефіцієнт тертя, хороша хімічна стійкість, що забезпечило високий ресурс досліджуваних деталей у будь-яких умовах експлуатації.

**Ключові слова:** зносостійкість, абразив, зварювання, плазма, ковш, шар, корозія, сталь.

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<sup>1</sup> Робота виконана під керівництвом професора Глушкової Д.Б.

## Introduction

Technology engineering - the field of technical science, which engaged study connections and installation patterns in the process manufacturing machines. It is designed to develop theory technological provision and promotion quality products engineering with the smallest cost price their release , as well as ensure the ecological safety of production. When choosing a material and methods of its strengthening, first of all, it is necessary to comprehensively consider the conditions of its operation and rank the factors affecting the material according to the degree of their influence on the reliability of the machine or mechanism. Necessary form technical material requirements on the basis of tribological tests, as well as on the basis of bench and industrial tests [1].

The correct choice of material for the manufacture of the considered parts, as well as the method of their strengthening, is an urgent and important task.

## Relevance of development

### Working conditions and causes of failure of teeth of excavator buckets

Tooth refers to constructive elements excavators and others earthmoving machines, namely to their details workers organs and methods their manufacturing. Excavator bucket tooth consists from an adapter whose shank has corresponding slots for attachment to buckets excavator (fig. 1, 2).



Fig. 1. General view of the bucket



Fig. 2. Loss of shape of teeth of excavator buckets

According to practical observations, after the production of 35,000 cubic meters of sand-crushed soil, the teeth of the excavator bucket are in the stage complete wear and tear. Their sharpening angle increases by 2.5 times, and working length is decreasing more than 3 times.

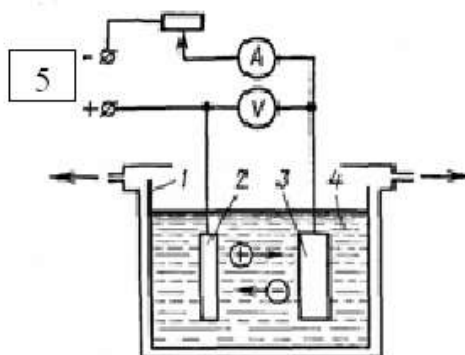
A similar state of the working body is common lowers general productivity construction special equipment, because all the energy engine excavator aimed not at work, but at overcoming new ones obstacles

### Types of protection and restoration of teeth

Alteration by electroplating.

They are widely used in enterprises galvanic processes. They are used for compensation wear and tear workers surfaces, as well as when applied to parts anti-corrosion and protective and decorative coverage.

Galvanic coating receive with electrolytes, as whose apply water solutions metals, which necessary to cover details (fig. 3). Cathode with electroplating sedimentation metals with electrolytes is in renewable part, anode - metal plate. Soluble anodes are made with metal which settles on the part, insoluble anodes - with lead.



1 - bath with dielectric ; 2 - soluble anode ; 3 - cathode ( product );  
4 - electrolyte; 5 - current source

Fig. 3. Scheme of electroplating

But, unfortunately, these methods do not give stable industrial results. In addition, they are not dangerous both for the environment and for those who work with them [2]. Therefore, recently, the most promising method of applying protective coatings is plasma spraying, in which heating, melting, spraying and the transfer of the sprayed material is carried out by a plasma jet obtained by heating the gas flow in an electric arc discharge. Effective about will protect metal worn out the surface from abrasive wear use became and with increased strength characteristics.

The experience of industrial enterprises recently proved the expediency of increasing the durability of the considered parts due to the use of surface strengthening methods.

In mechanical engineering, such coating methods as detonation and plasma are used.

These methods have a number of advantages:

- limited thermal influence,
- reduction of deformation.

At the same time, the properties of coatings and their structure have not been sufficiently studied

The task of choosing the optimal properties of the working layers is solved purely experimentally. In this regard, conducting research to identify the possibility of using different methods of applying coatings to increase the durability of the teeth of the excavator buckets is an important and urgent task.

In this work, we used the technique of ion-plasma coatings to increase the durability of the teeth of excavator buckets.

### Material and research methodology

Research materials.

In most cases, the teeth of excavator buckets are made of 09G2S steel, the chemical composition of which is shown in table 1.

The stability of properties in a wide temperature range allows the use of parts from this brand in the temperature range from -70 to +450 C. The properties of 09G2C steel are: with steel 09G2 S after processing on a two-phase structure has increased limit of endurance; simultaneously the number of cycles to destruction in the area increases by approximately 3-3.5 times low - cycle tiredness (fig. 4).

Table 1 – Chemical composition of 09G2S alloy

Steel	Availability chemical elements , %								
	C	Si	Mn	Cr	No	S	Cu	As	P
09G2S	0.12	0.5-0.8	1.3-1.7	0.3	0.3	0.04	0.3	0.08	0.035

Disconnection others areas of martensite and high plasticity ferrite much make it easier initial plastic deformation.

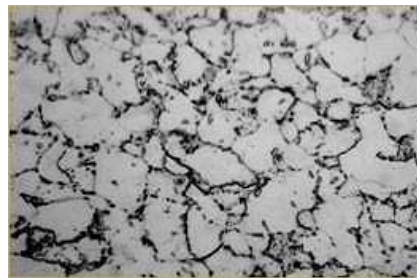


Fig. 4. Microstructure of steel 09G2S,  $\times 1000$

To detect changes in the surface areas, as well as to control the quality of the coating, hardness measurements were carried out. This method makes it possible to carry out 100% control of parts, tests are not destructive, measurements can be carried out directly on the parts. The Rockwell method was used for the study, which is usually used to study heat-strengthened material.

To determine the hardness of individual particles, as well as its anisotropy in different areas of the coating, the microhardness measurement method was used in the work (fig. 5).

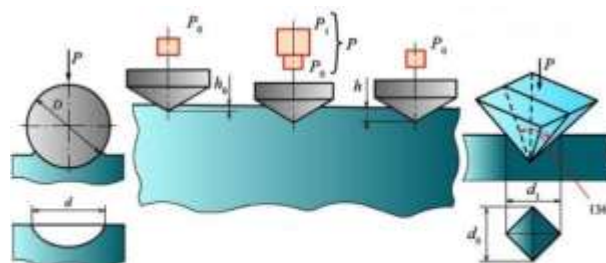


Fig. 5. Hardness measurement

Metallographic analysis.

The structures were studied and photographed on an Altama MET 1 microscope at a magnification of (70 - 1000) times (fig. 6).

The structure of the surface before and after operation was studied using a SEM scanning electron microscope at an accelerating voltage of 30 kV in a wide range of magnifications from 20 to 10 thousand times. To analyze the phase composition of the base metal and coating, X-ray structural phase analysis was performed on the URS-50 unit.

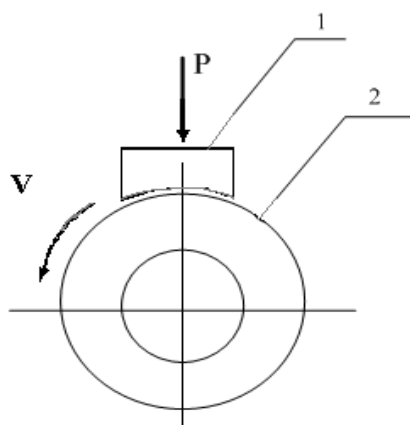
Methods trial materials for friction and wear .



Fig. 6. Altama MET 1 microscope

For assessment efficiency application materials , methods their processing , constructive changes in details and others measures were used laboratory and bench test that modeled the maximum approximation to real operating conditions .

The tests were carried out on a car friction SMC - 2, which allows comparison research subjects materials on wear resistance , antifricition and their properties in the process making according to the "roller- block " scheme (fig. 7) .



1 – stationary sample ( block ); 2 – movable sample

Fig. 7. Wear test

Tribotechnical characteristics are the main criteria for assessing the workability of materials for volumetric hydraulic drive parts and the effectiveness of their surface treatment.

In touch with hereby for conducting this one work selected methods tests which allow simulate the main ones processes friction and wear real details.

Galvanic technique chrome plating

Process electrolytic application of chromium is based on the method electrolysis metals. Its essence consists in passing electric current through the electrolyte. Electrolyte is solution in which are included chromium salts, acid or alkali. When passing electric current with solution chrome anhydride and sulfuric acid stand out chromium cations which settle on the processed surface.

Galvanic process chrome plating lead to the following average parameters:

- chromic anhydride - 250 g/l;
- sulfuric acid - 2.5 g/l;
- temperature - 50 ° C for decorating details and 55-60 °C to receive functional surfaces ;
- current density – 25 A / dm<sup>2</sup> for decoupling and 60 A/dm<sup>2</sup> - functional chrome-plated surfaces (fig. 8).

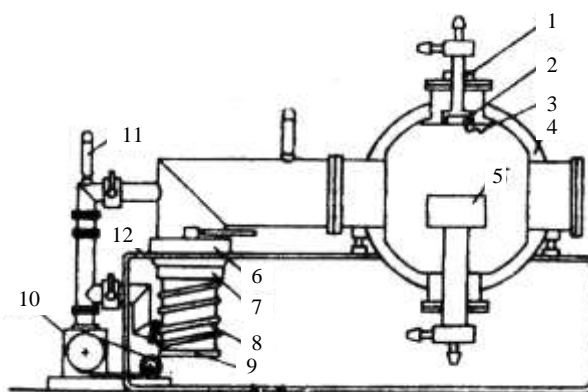


Fig. 8. Installation for galvanic chrome plating

High-quality electroplating depends from temperature electrolyte and current density. Tsi and parameters affect the external appearance and characteristics of the applied layer.

Method of applying plasma coating.

The application of plasma coating was carried out on the Bulat-3T installation (fig. 9). It consists of a chamber, a vacuum pumping system, evaporators, a rotary device, a water system and a stand [3].



- 1 - I focus on the camera ; 2 - cathode; 3 - incendiary electrode ;  
 4 - chamber-anode; 5 - layer ; 6 - nitrogen a trap  
 7 - water a trap 8 - high vacuum unit; 9 - heater ;  
 10 - form vacuum pump; 11 - monometric lamp;  
 12 - water cooling system of the installation

Fig. 9. The general scheme of the Bulat-3T installation

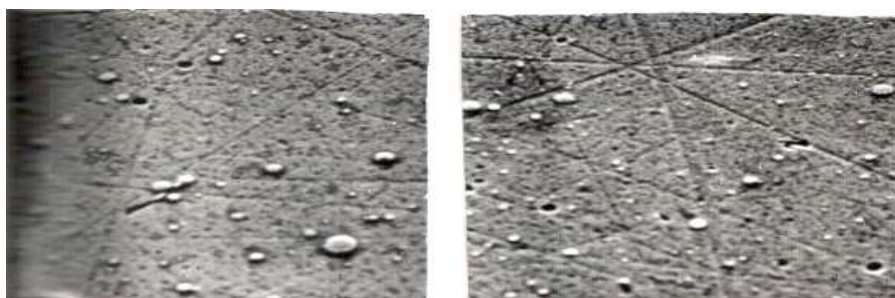
The camera is a cylindrical vessel with in and out with a diameter of 500 mm and 500 mm long, in which flowing process spraying. On camera and lids are located six nozzle and in with flanges to which are attached: window review; device rotary; evaporators and adapter to the system vacuum pumping out.

Parameters process application, primarily the condensation temperature and speed application, determine properties cover Condensation temperature, which depends mainly on properties material pads, support constant for everything process causing cover.

#### **Influence of ion plasma chrome plating on the durability of excavator bucket teeth**

Development of optimal technological parameters of deposition of plasma coatings in the heating temperature were selected as optimal application parameters the substrate on which the coating is applied, and the deposition time [4-5].

As is known, the main parameter of the process of condensation of matter under conditions of ion bombardment is the pressure of the reaction gas. This parameter is determined in each specific case and depends on the composition of the cathode, the model of the installation on which the coating is applied, and the operating conditions (fig. 10).



nitrogen pressure a –  $3 \cdot 10^{-2}$  Pa; b – 1.0 Pa

Fig.10. The microstructure of the obtained chromium nitride coating at different nitrogen partial pressures

According to the technical data , the temperature in the chamber of the Bulat 3T installation varied from 300 to 800 °C.

Ion bombardment has a positive effect on the part at its temperature of 500-800 °C, which exactly corresponds to steel 09Г2С and gives the best adhesion of the coating to the part and, accordingly, the highest wear resistance of parts with such a coating during operation (fig. 11).



Fig. 11. Steel surface after bombardment with chromium ions,  $\times 1000$

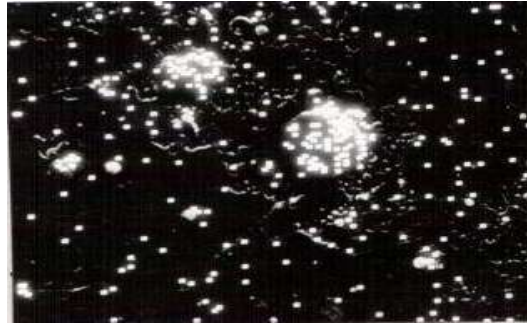


Fig. 12. Microdistribution of chromium on the surface after ion bombardment,  $\times 1000$

The time of applying the CrN coating is  $10 \mu\text{m} / \text{h}$ . Taking into account that the most adhesive activity of coated substrates is possessed by chromium nitride coatings with a thickness of 2 to 5 microns, the coating time ranged from 12 to 30 minutes.

When chromium nitride coatings are applied to the working surfaces of teeth made of 09G2C steel, the best adhesion occurs (fig 12).

At lower temperatures, there is a tendency to decrease the adhesion of the coating, which is accompanied by peeling of the coating during operation, this phenomenon is especially noticeable when the heating temperature of the surface to which the coating is applied exceeds the tempering temperature of the steel due to the strengthening of the latter .

Coating time is also an important parameter to be optimized (fig. 13).

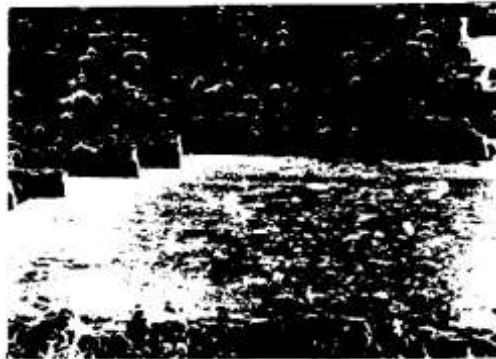


Fig. 13. The initial stage of exfoliation,  $\times 1000$

A significant increase in wear resistance is achieved when the substrate is heated to a temperature of  $500 \text{ }^\circ\text{C}$ .

### **Laboratory studies of restored teeth**

To prove the advantages of the developed method of processing the teeth of excavator buckets over other methods, it is necessary to conduct comparative tests parts made by various methods used in industry at this time.

Of all the changes in the properties of surfaces, the increase in resistance is most evident during tests on friction machines.

The conducted tests showed that burrs appear in the coating obtained by the galvanic method under a load of 800 N. At the same time, the coating obtained by ion-plasma sputtering works without the appearance of burrs under a load of up to 1000 N. Thus, the degree of increase in anti-burr properties multi-layer coating of the tooth, the vacuum-plasma method gives the greatest effect.

In galvanic coatings, significant surface destruction is observed,

For galvanic coatings, although high values of the coefficient of friction (up to 0.6) are also characteristic, but when the load increases, its sharp increase is not observed, and even at 800 N, its value is 0.63-0.65 (fig. 14, curve 3). At the same time, coatings obtained by high-frequency current treatment are characterized by a low coefficient of friction (0.2) at low loads - at the level of 200 N. As the load increases to 600 N, the value of the coefficient of friction increases to 0.25. When the load is higher than 600 N, there is a sharp increase in the friction coefficient - up to 0.45 (fig. 4, curve 2). This shows that multilayer coatings cannot withstand high loads under dry friction conditions.

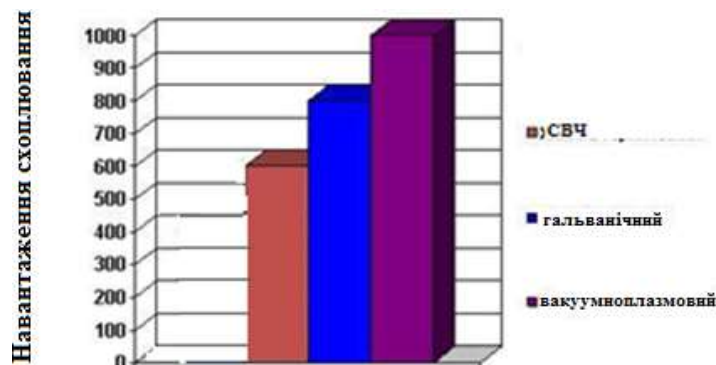
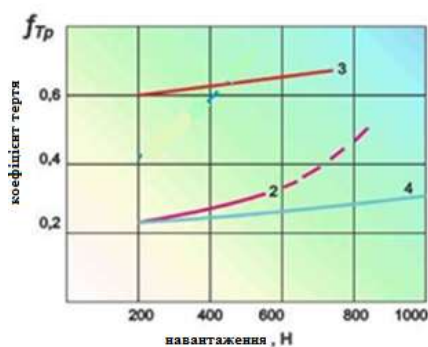


Fig. 14. The influence of the type of application of a multilayer coating on the sliding friction resistance

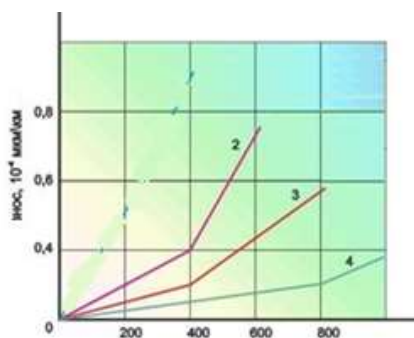
For ion-plasma coatings under loads from 200 to 1000 N, the coefficient of friction remains almost constant - 0.20-0.23. Thus, the proposed method makes it possible to reduce the coefficient of friction by 2.5-3.0 times compared to galvanic coatings (fig. 15).



1 – treatment with high frequency currents; 2 – galvanic method;  
3 – ion-plasma method

Fig. 15. The effect of the type of coating on the change in the coefficient of the friction pair

The dependence of the intensity of wear on the specific pressure retains a linear character for all types of processing (fig. 16).



1 – treatment with high currents frequencies , 2 – galvanic method,  
3 – ion-plasma method

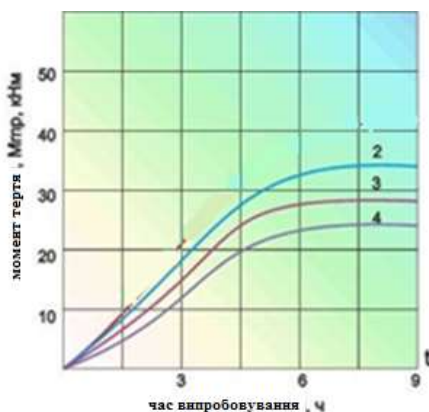
Fig. 16. Influence of the coating method on linear wear of casting samples

For coatings treated with high-frequency currents are characterized by a smooth increase wear to a load of 400 N, then with increase load up to 600 N is observed strong magnification intensity wear up to  $0.78 \cdot 10^{-4} \mu\text{m}/\text{km}$ . The coatings obtained during treatment with high-frequency currents are in the data conditions slightly increase durability multi-layered cover

Coatings obtained by the galvanic method have wear ( $0.2 \cdot 10^{-4} \mu\text{m}/\text{km}$  when the load increases to 800 N).

Ion-plasma coatings are characterized by minimal wear at all tested loads from 200 N to 800 N. Wear is at the level of  $0.2\text{--}0.39 \cdot 10^{-4} \mu\text{m}/\text{km}$ . Conducted studies have shown that the ion-plasma method of applying a multilayer coating increases the wear resistance of the material by 1.6–1.7 times compared to the galvanic method, by 2.1 times – with high-frequency current treatment.

As the tests showed, stabilization of the friction moment occurs faster in friction pairs with ion-plasma coating, why after other types of processing (fig. 17).



1 – treatment with high frequency currents;  
2 - galvanic method; 3 – ion-plasma method

Fig. 17. Effect of different coating methods at the moment of friction and wear of the friction pair

In ion-plasma coatings, it occurs at a load of 1400 N, in coatings obtained by chemical-thermal treatment - 1600 N, in coatings obtained by the galvanic method - 1500 N. Analysis of the curves of the dependence of the wear of the friction pair on the duration of running in shows that the coatings have the least wear during running in , obtained by ion-plasma sputtering.

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Thus, comprehensive studies of fatigue, anti-friction properties and wear resistance of the multilayer coating revealed the following advantages of the developed method of applying the coating in comparison with the existing ones (high-frequency currents, galvanic method):

- increased carrying capacity;
- increased wear resistance;
- reduction of the friction coefficient;

Such significant advantages make it possible to recommend the developed method for processing the teeth of excavator buckets in order to increase their wear resistance and performance with the corrosive influence of the environment, and can be recommended for practical use.

### **Conclusions**

1. The results of tests of the teeth of excavator buckets strengthened by ion-plasma chromium by the method of substance condensation under ion bombardment (IBM) conditions show that their wear resistance is increased by 1.75 times compared to the original ones that were not subjected to special strengthening.

2. The conducted research made it possible to establish that the optimal technological parameters for applying plasma coatings to the teeth of excavator buckets are a nitrogen partial pressure of 1 Pa, a surface heating temperature of 500–550 °C. The surface roughness on which the coating is applied is  $R_a = 0.16 \mu\text{m}$ , the thickness of the applied coating is 5  $\mu\text{m}$ .

3. The improved technology of ion-plasma chrome plating ensures the operation of hardened parts without chips and cracking of the coating, and meets the conditions of environmental and security

4. The wear resistance of the studied details increased by 1.75 times.

5. The work was implemented at SE "Kharkiv Mechanical Plant" in the educational process in the courses "Technology of coating", "Increasing corrosion and wear resistance".

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