Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 149 (2019) 319–323

Procedia Computer Science

www.elsevier.com/locate/procedia

ICTE in Transportation and Logistics 2018 (ICTE 2018)

Modification of sprayed with supersonic coatings by microplasma oxidation

Serik Nurakov[a,]*, Marat Belotserkovsky[b], Gulnara Merzadinova[a], Kurmet Aitlessov[a]

[a]Eurasian National University named after LN Gumilyov, Satpayev 2, Astana, KZ-010008, Kazakhstan
[b]Belarusian National Technical University, Independence 65, Minsk, BY-220007, Belarus

---

Abstract

Due to the fact that the increase in the efficiency of transportation processes directly depends on the reliability of transport equipment, this article discusses the method of hardening the surfaces of parts of transport machines with a new efficient oxidation technology. The process of obtaining multilayer composite systems by combining supersonic gas-flame spraying of an aluminum coating with subsequent microplasma oxidation to obtain oxide-ceramics was studied. The structure and composition of the treated coating was studied. An increase in the porosity and microhardness over the depth of the layer was revealed.

Keyword: Transport equipment; Multilayered composites; Aluminum coating; Oxidation; Porosity

---

1. Introduction

In world practice of the production and use of transport equipment in recent years pays great attention to technical advances and to improving the wear resistance of surfaces of parts by the method of oxidation. An effective way to solve the problem of increasing the operational characteristics of coatings made of wire materials with super-sound coatings can be the formation of high-strength surface layers with a multilayer structure in them by using various economical methods of surface hardening.

---

* Corresponding author. Tel.: +7(701)-513-70-24; fax: +7-717-270-9457.
E-mail address: enuter@yandex.kz

1877-0509
10.1016/j.procs.2019.01.142

2. The theoretical basis of the research method

It was suggested that coatings that are layered composites of the metal-metal + carbide, metal-metal + solid lubricant, metal-oxide-ceramics, metal-polymer, polymer-metal-oxide-ceramics types can have such a complex of properties that is not provided by the application of monolayers, or is possible only with the use of expensive high-energy methods for the formation of coatings.

The research was carried out to develop and test in practice the technologies for the formation of multilayer composite systems based on a combination of the supersonic gas-flame application of an aluminum coating followed by microplasma treatment. The technology of microarc (microplasma) oxidation allows us to modify the surface layer of aluminum and its alloys in oxide-ceramics [1]. For the formation of oxide-ceramic coatings by the method of anodic-cathodic microarc machining, specially developed equipment was used, which makes it possible to control the processing regimes in a wide range of regulation [2].

Microarc oxidation was carried out at an medium frequency (8 kHz) at a voltage of 420 V, current density of 15-30 A / dm2 in a modified electrolyte, the main components of which were dissolved in distilled water liquid glass Na_2SiO_3 with a modulus of 3-3.4, density 1.4-1.5 g / cm3 (GOST 13087-81) - 4-6 g / l and potassium hydroxide KOH brand "h" (GOST 9285-78) - 3 g / l.

The most rational frequency range is determined from the expression [3]:

$$f_{э} = \frac{\gamma_n^2}{4\pi(R_2 - R_1)^2 \mu_0 \rho_n} \tag{1}$$

where:

- $f_{э}$ is the frequency of the electromagnetic field, 1 / s;
- γ_n^2 is the ratio of the coating thickness to the depth of the saturable layer in coating, mm;
- R_1 – cavity radius, m;
- R_2 – part radius, m;
- μ_0 – $4*10^{-7}$ gN / m;
- ρ_n– specific electrical conductivity of the coating material.

3. The results of spraying with supersonic coatings

The analysis of the obtained results showed the following. The nature of the processes of microarc oxidation of sprayed coatings practically did not differ from those described in the scientific and technical literature and observed in the processing of cast and rolled aluminum. This conclusion was confirmed by studies of the microhardness of coatings on the depth of the oxidized layer and the evaluation of their composition. Sputtered and micro-arc oxidized coatings had a non-uniform in depth structure and composition (see Fig. 1).

In the coating, four zones are clearly distinguished: a layer of sprayed aluminum, which did not change its composition after microarc oxidation; the transition zone between the oxidized layer and aluminum; a basic oxidized layer; loose surface layer. The region with the highest hardness 8.6-10.5 GPa, indirectly indicating the presence of solid-state solutions of aluminum alloy components with α-Al_2O_3 and γ-Al_2O_3oxides, was located at a distance of 45-55 μm from the transition zone to the unoxidized coating material, and at the transition to the surface, the hardness decreased to 3.7-5.6 GPa.

The porosity of the coatings as a result of oxidation (porosity of the oxidized layers) increased to 10-13% in the zone with a maximum microhardness and up to 20% on the surface of the oxide.

During the research, the oxidation time was reduced by 8-15% with increasing surface porosity of the sprayed layer. However, the maximum hardness of the oxidized coating decreased. The increase in the volume porosity of the coatings obtained during the sputtering process made it possible to significantly increase the thickness of the oxidized layer.

The reverse effect occurred when the oxygen content (the amount of oxides) was increased in coatings obtained by electric arc metallization, hypersonic metallization [4], and flame-gas-spray wire spraying (see Fig. 2).

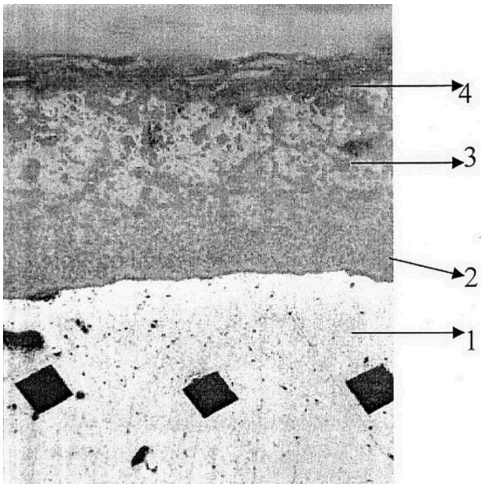

Fig. 1. Spray coating with oxidized layer:
1 - layer of sprayed aluminum; 2 - transition zone between the oxidized layer and aluminum; 3 - basic oxidized layer; 4 - loose surface layer.

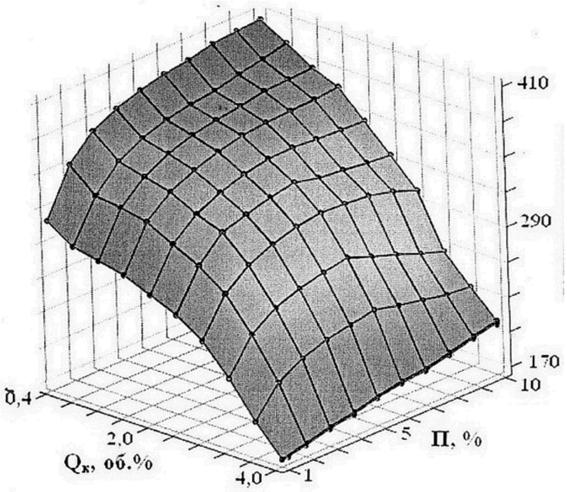

Fig. 2. Effect of the porosity of the coating and the oxygen content on the thickness of the oxidized layer.

The results of the change in hardness and the porosity of the coating formed in the process of oxidation along the thickness of the layer (see Fig. 3) are close to the data obtained by other researchers [1], but they have a number of the following features:

- Microhardness of the sprayed and oxidized layer below the microhardness of the oxidized compact material, which may be due not to the composition of the oxide ceramics but to the presence of porosity in the gas thermal coating itself
- The upper part of the sprayed coating has a pronounced loose surface layer with open porosity and cracks to a depth of 0.2-0.3 of the thickness of the oxide-ceramic layer

For the comparative evaluation of the wear resistance of oxidized layers, samples of high-strength cast iron of grade VCH50-7, hardened by heating with a gas flame and cooling in oil, were tested to a hardness of 50-55 HRC.

The rate of wear of the samples with dry friction was from 320 to 400 μm / km, which is 2 or more times higher than the wear rate of zone 3 of the oxidized sprayed coating.

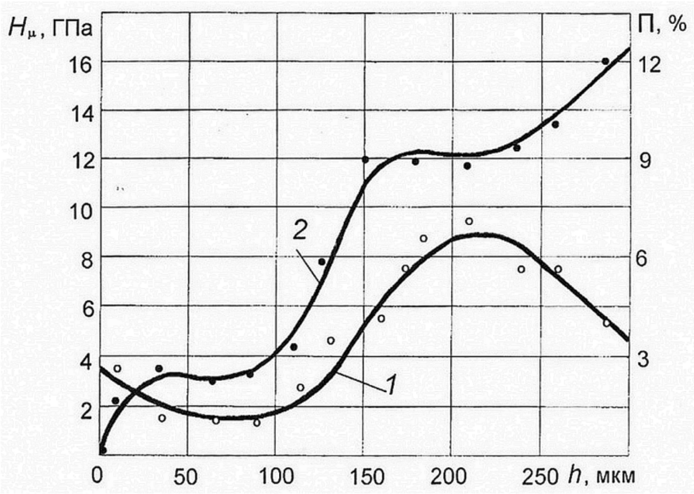

Fig. 3. Distribution of microhardness (1) and formed porosity (2) over the depth of the layer.

Tests on the modernized friction machine SMC-2 in the friction mode with limited lubricant supply (TAD-17 oil) showed that in the range of loads from 2 to 4 MPa for the zone 3 of oxidized coatings the conditions of normal mechanochemical wear are realized, and the wear rate is within 5 -7 μm / km (see Fig. 4).

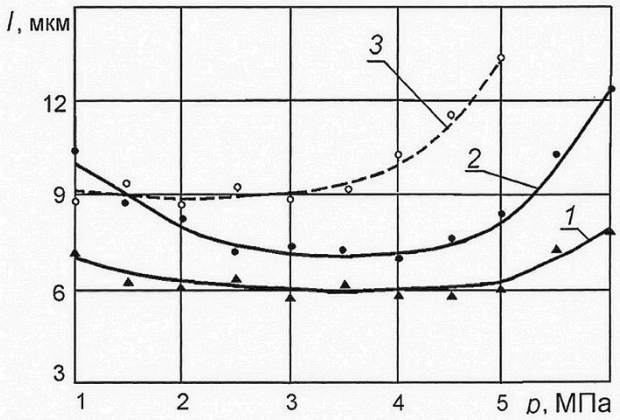

Fig. 4. Effect of pressure on the wear rate of coatings:
1 - oxidation; 2 - coating of steel 40X13; 3 - cast iron HF50-7 (V = 1.05 m/s).

Increasing the specific load over 4.5 MPa leads to a proportional increase in wear. At a specific load of about 3 MPa, the wear rate of the oxidized coating is practically equal to this value for the sprayed layer of 40X13 steel and 50% lower than for VCh50-7 cast iron. Given that the coatings of steel 40X13 have good adhesion to lubricants and are used to repair the necks of crankshafts of ICE, it can be assumed that the oxidized coating can also be used in sliding friction units with lubrication at specific loads up to 5 MPa and low sliding speeds.

Since the thickness of the solid oxide layer does not exceed 200-250 μm, which is caused by the nature of the microplasma treatment process, the possibility of sputtering on the oxidized layer of the aluminum coating, its oxidation, sputtering of the next coating, etc. was evaluated. A multi-layer composite was prepared (see Fig. 5) [5], and it was found that after jet-abrasive treatment the adhesion of the sprayed aluminum coating to the oxide is 20-25 MPa.

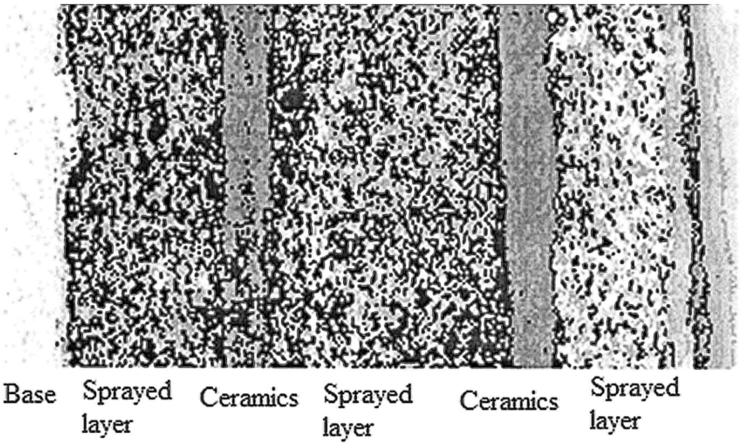

Fig. 5. Cross section of a multilayer composite (x70).

4. Conclusion

Thus, the height of the sprayed aluminum coating can be easily controlled both during the spraying process and by subsequent machining, and therefore it became possible to obtain the formation of sufficiently "thick" layers of ceramics (up to 1.5 mm) with thin (10-40 μm) interlayers aluminum with high mechanical properties. Tests of oxidized coatings showed that the wear rate is in the range of 5-7 μm/km. According to this indicator, the oxidized coating is equal to the data of steel 40H13. According to the results of the study, it was concluded that the height of the deposited aluminum coating can be easily controlled both during the deposition process and by subsequent mechanical processing.

References

[1] Malyshev, V.N. (1996) "Features of formation of coatings by the method of anodic-cathodic microarc oxidation". *Protection of metals.* T.32, **6:** 662-667.

[2] Basinyuk, V.L., M. A. Belotserkovsk. (2003) "Development of technology and application of multi-layer composite coatings based on oxide ceramics". *Friction and wear.* T.24, **2.**: 203-209.

[3] Dorozhkin, N.N., V. T. Sakhnovich et al. (1986) "Production of composite gas-thermal coatings using induction and magnetic pulse treatment". *Electrophysical technologies in powder metallurgy. Abstracts of the International Conference. Riga,*: 54.

[4] Nurakov, S., M. A. Belotserkovsky. (2014) "Intensification of gas-flame spraying processes by high-speed flows". *Bulletin of ENU named after L.N. Gumilyov.* **3 (98).** :180-189.

[5] Belotserkovsky, M.A. (2009) "Technologies for the formation of layered coatings of dissimilar materials". *Strengthening technologies and coatings.* **3.** :49-53.

Serik Nurakov, doctor of technical sciences, professor, director of research laboratories at the Eurasian National University named after L.N. Gumilyov, Astana, Republic of Kazakhstan. He has more than 370 publications: patents, monographs, textbooks and teaching aids, standards, SSaRs, including abroad. Head of a number of scientific and technical projects. The field of scientific activity is mechanical engineering, technical service, construction, standardization. Contact information: 2 Satpayev str., Astana, Kazakhstan. Tel.: +7(701)-513-70-24. Contact him at enuter@yandex.kz.