Processing of Duralumin Surface by a High-Speed jet of Electric-Discharge Plasma

A.A. Sivkov, D.Y. Gerasimov, A.S. Tsibina

Scientifically research institute of high voltage
634050, Russia,. Tomsk, av. Lenina, 2a; (3822)- 563-682, E-mail: SivkovAA@mail2000.ru

Abstract – Impulse coaxial magneto-plasma accelerator supersonic stream of electrodigit plasma. With a barrel length of up to 250 mm, the discharge is accelerated by a current (100÷150) кA to a velocity of (3÷5) km/s at atmospheric pressure. Up to 10 g of metal is taken out of a barrel. Researches on a raster electronic microscope have shown: uniformity of a covering, absence of pores and a dense interface from a surface of a substrate. The formation of a boundary layer of mutual mixture of materials of a covering and substrate by thickness (50÷150) μm is established. It causes an extremely high adhesion of a covering from stainless steel on duralumin. A great number of jet inclusions of dense substance extending in thickness of a substrate starting from ~150 μm up to 500 μm have been found out. This layer has high nanohardness. Increase of wear resistance of a surface for more than on two order. The processing of a surface of the details made of aluminium alloys by a high-velocity stream of electrodigit plasma of structure of stainless steel provides an essential increase of mechanical properties. The received covering can carry out anticorrosive functions and functions of thermal barrier.

The aluminium alloys are widely used in modern engineering. The details and elements of constructions produced from them, often work in conditions of high temperature pressure and fluid and gas fluxes velocities. Thus the only way of deciding a number of practical questions is the deposition of different functional coatings. However ordinary coatings and even coatings that were deposited by plasma method [1] are characterized by final adherence and can be separated from the surface in critical conditions. The density of the coating can be increased by creation of such conditions and their deposition that the mutual mixture boundary layer of coating material and surface will be forming. This is achieved by the use of high enthalpy fluxed that is produced by the impulse accelerators. Unlike the explosive and electrothermal [2, 3] accelerators, the hybrid coaxial magnetoplasma accelerator (HCMPA) high current discharge of Z-pinch type has an essential advantage [4, 5]. This work presents the results of experimental investigations of duralumin samples (D16) which were obtained by high velocity flux produced by electrodischarge plasma, produced by HCMPA in atmospheric conditions. In Figs. 1 and 2 there are presented microphotos of duralumin substrate vertically cuts sections with composite coating of TiC + Ti composition (Fig. 1) and stainless steel composition (Fig. 2) received with the help of scanning electron microscope Jeol-840. Coatings can reach millimeter thickness.

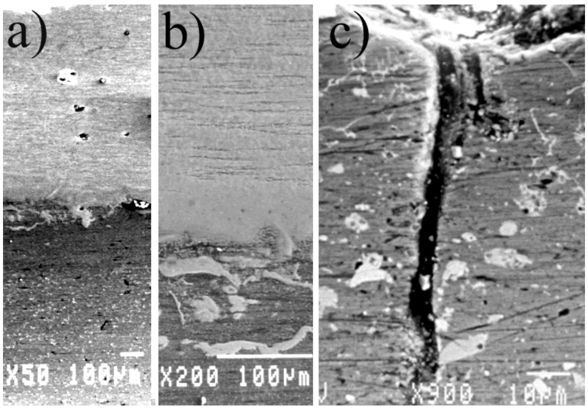

Fig. 1. Microelectron photos of the vertical cut section of the duralumin sample with composite material coating Ti + TiC composition: *a*) survey photo, up-coating, down – substrate; *b*) fragment of the boundary layer of material mutual mixture; *c*) fragment of the etched section with the channel of superdeep penetration

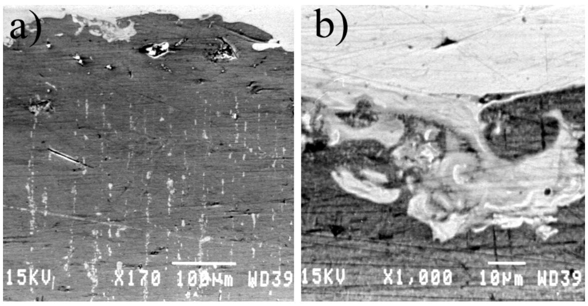

Fig. 2. Microelectron photos of the vertical cut section of the duralumin sample with stainless steel coating: *a*) survey photo, up-coating, down – substrate; *b*) fragment of the material mutual mixture boundary layer

They are characterized by high density, absence of pores and absolutely dense adjoining to the surface of substrate. On the boundary of the interface the layer of material mixture of ~ 100 μm thickness is formatting, that is distinctly seen on the microphotos and is proved by X-ray photoelectron spectroscopy (X-ray PES) data. Electron spectroscopy of the surface of stainless steel sample section, obtained by plasma flux snows carbon, oxygen and iron saturation of the layer with the thickness more than 300 μm (Fig. 3).

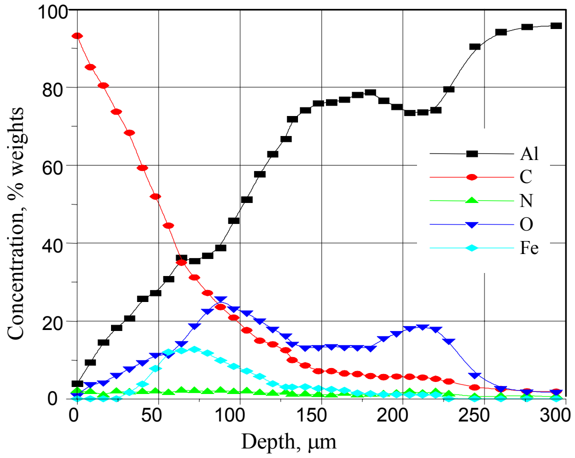

Fig. 3. Curvet of mass elements concentration in boundary layer of the aluminium substrate surface obtained by plasma flux of stainless steel composition. The data received by electron spectroscopy method

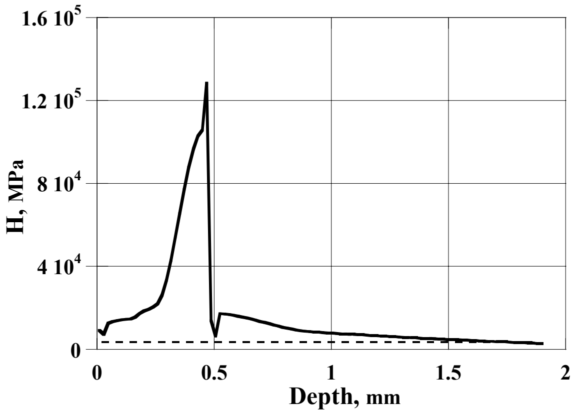

Fig. 4. The curve of nanohardness of the duralumin sample surface boundary layer obtained by plasma flux of stainless steel composition

Iron is the basic component of highvelocity flux, oxygen and carbon are captured from the air. A big amount of carbon presents in flux as basic product of electrothermal decomposition of hydrocarbon gasogenerating substance (technical vaseline), that is put into plasma structure formation zone in the accelerator in order to increase it's dynamic parameters. If necessary it's presence could be essentially decreased. It is seen on microphotos (Figs. 1, *a* and 2, *a*) that the substrate layer is of several hundreds micron thickness and is saturated by dot and jet inclusions of more dense flux substance. Cross dimension of inclusion is approximately (1÷5) μm. On the substrate etched section (Fig. 1, *c*) typical channels of superdeep penetration age discovered. Plurality and geometry of channel of jet superdeep more dense substance penetration can be explained, as we cansider, only by occurrence of microcumulative processes when highvelocity dense flux meets substrate [4]. The received data allows to explain great increasing of nanhardness of duralumin substrate surface layer with the thickness more that 0.5 mm. The results of investigations of heated up at 325 °C stainless steel coated sample's nanohardness are presented on the Fig. 4. it is seen that mutual mixture layer has nanohardness which is close to nanohardness of steel. While deepening nanohardness is gradually increasing and on the depth of ~ 250 μm reaches $2 \cdot 10^4$ MPa. Further it sharply increases kill 10^5 MPa on the depth of ~ 0.45 mm, and sharply decreases till ~ $2{\cdot}10^4$ MPa with the following gradual discreasing till the normal value on the depth near to 2.0 mm.

In accordance with the data received great increasing of duralumin sample thick surface layer is explained as it's saturation with the influenced flux material with formation of carbide, oxide and nitride phases and cubic carbon in totality with shockwave condensation.

Table 1. Results tribological of tests of samples

°C	S_1, μm^2	S_2, μm^2	S_1/S_2
25	35349	306	115.5
125	134622	2391	56.3
225	94002	4124	22.8
325	767406	4804	160

In the table the comparative hightemperature tribological tests of duralumin initial sample and stainless steel coated samples are presented. Tests were carried out on high temperature (friction pare: boll-disk, sample-disk, indentor-boll 3 mm diameter). The wear is defined with the help of solid profilograph Micro Measur 3D station as the value of cross-sectional area of a circular track left by spherical indentor, S_1 – of initial sample, S_2 – of obtained one. The correlation of these values S_1/S_2 shows that wearprootness of the obtained sample was increased on (1÷2) units. Besides coating deposed in such a way can be used in anticorrosive and termobarrier functions. The totality of acquired properties allows to increase working parameters of details and constructive elements made of aluminium alloy, in particular, in combustion engines, working piston surface and in a combustion chamber.

This work was supported in part by the Russian Foundation for basic Research (project No. 03-01-00707).

References

[1] V.V. Kudinov, Plasma coatings, Moscow, Nauka, 1977, p. 1–184.

[2] K.N. Kozorezov, K.I. Mirkin, Fiz. Khim. Orbab. Mater., No. 1, 77–80 (2000).

[3] E.Ya. Shkolnikov, M.Yn. Guzyev, S.P. Maslennikov, N.N. Netchaev A.V. Chebotarev, Devices and engineering of experiment, No. 6, 130–135 (2000).

[4] A.A. Sivkov, A.P. Iliin, A.M. Gromov, N.V. Bychin, Fiz. Khim. Orbab. Mater, No. 1, 42–48 (2003).

[5] A.A. Sivkov, The applied mechanics and technical physics **42**, No. 1, 3–12 (2001).