Research of influence of mobile cathodic stains of the vacuum arc for reception of the adjustable roughness of metal surfaces

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Abstract. In the modern technics there is a requirement in micro- and macrorough surfaces of products for improvement of their operational characteristics (improvement of adhesive properties of various coverings, decrease in deterioration of rubbing details because of the best deduction of greasing, increase of the heat exchanging coefficient from a surface, stimulation of adhesive processes on sites of contact to a bone fabric of medical implants in stomatology and orthopedy etc.). In the given work the modes of reception regulated micro- and macrorough surfaces on samples from a titanic alloy and stainless steel by electrothermal influence of moving cathodic stains in the vacuum arc discharge are investigated. Chaotically moving stains, possessing high specific power allocation (~ 10^7 W/cm^2), "scan" the difficult design of a product, including "shadow" sites, doing rough its blanket. The sizes of roughnesses are regulated by a current and time of influence of the discharge, pressure in the vacuum chamber and a number of other parameters. The scheme of experimental device, photo and the characteristic of rough surfaces and technological modes of their reception are resulted.

1. Introduction
In various areas of modern science and technology there is a need in micro- and macrorough surfaces of products for the improvement of their operational characteristics.

Let us list a number of such areas:
- improvement of adhesive properties of various coverings, including paint and varnish.
- Improvement of ergonomic and decorative characteristics in demanded cases, for example, giving of a necessary roughness of a contacted surface of a product, as in the known technological process of mechanical knurling.
- Decrease in deterioration of rubbing details (the minimum deterioration appears not on smooth surfaces, and at some optimum values of roughnesses because of the best deduction of greasing) [1].
- Increase in the heat-removing coefficient from a surface at the increase in its roughness (an intensification of heat exchange at the expense of increase in the general heat-removing surface and the changes of characteristics of a heat-carrier current) [2].
- Improvement of hydro- and aerodynamic characteristics of the flow around bodies by liquids and gases with a stream separation in certain ranges of Reynolds numbers [3].
- Stimulation of adhesive processes on sites of contact to a bone fabric of medical implants in stomatology and orthopedy (the rough well moistened surface of an implant containing roughnesses, fabrics proportional to bio cages is necessary) [4-5].

Implants are made of biocompatible titanic alloys and stainless steels. Their sizes are in a range from several millimeters to several centimeters. There is a considerable quantity of designs of...
implants. For example, only in tooth implantology cylindrical, cone-shaped, lamellar, disk, screw, hollow, frame and other designs are applied. The rough surface of an implant should not contain sharp edges and easily separated particles [5].

Now such surfaces receive, basically, methods of powder metallurgy, sand-streaming and plasma spraying. These methods have lacks. For example, at the plasma spraying there is a problem of adhesion of a covering (Figure 1) and difficulty of processing of products with the difficult form (hollows, shadow sites).

![Figure 1](image)

**Figure 1.** Macrorough surface obtained by plasma spraying: a – optical zoom x8, b – optical zoom x56.

### 2. Method of the reception of an adjustable roughness on metal surfaces

In the works devoted to studying electrode processes in vacuum arc electric discharges (look, for example, fundamental works [6–8]) the formation of rough electrode surfaces as a result of action of cathodic (or anode) moving stains is mentioned. In work [9] the reception possibility of micro- and macroroughnesses on metal surfaces by means of a vacuum arc has also been shown. But the characteristics of a received roughness and management possibilities in its parameters were not studied. In a number of works [10–16] the analysis is carried out and the theoretical methods of forecasting of a received roughness are offered.

The novelty of the given work is that in it the experimental research of vacuum arc modes for reception of the necessary (set) roughness of surfaces of products by electrothermal action of moving cathodic stains was carried out. Chaotically moving stains, possessing high power allocation (~ $10^7$
W cm\(^{-2}\)), "scan" a product configuration, doing rough its blanket. As cathodic stains, unlike anode, also clear a surface from various pollutions (sites with the smaller exit work of a material – the places of oxides, carbides, nitrides, etc.) in this work, the modes when samples (products) were cathodes in discharges were investigated only.

3. The description of the experimental device and results of research

Experimental research of the reception of roughnesses on metal surfaces was carried out on the device which scheme is presented on Figure 2. The device consists of the vacuum chamber 1 in which the processed sample (cathode) 2, the coaxial anode 3 and the unit of discharge initiation 4 are located. The chamber is pumped out by the system of rotational pumps to pressure of 10\(^{-2}\) mm Hg and the necessary working pressure is maintained in it.

![Figure 2. Scheme of the experimental device: 1 – vacuum chamber, 2 – sample (cathode), 3 – anode, 4 – unit of arc discharge initiation, 5 – pumping system, 6 – oscillograph, BT – thermopair gauge, G – rectifier, L – inductance, R\(_{sh}\) – shunt.](image)

In a number of investigated modes the chamber was filled with argon to a demanded pressure. The pressure in the chamber was monitored by the vacuummeter with thermopair gauge BT. Power supplies of the arc discharge was carried out from the rectifier G of thyristor type with the inductance consistently included in a chain \(L \approx 10\) mH which provided necessary stabilization of an arc. Arc initiation was carried out by a cathode contact with an additional mobile electrode 4. The current \(I\) and voltage \(U\) of the discharge was controlled by analog devices; in addition for the purpose of studying of temporary discharge characteristics filing of oscillograms of current and voltage on the memorable oscillograph was carried out.

Samples for research were made of titanic alloy VT-5 (Grade 6 US) and had working surfaces of two kinds: a cylindrical surface in diameter of 11 mm and length 15 mm and a conic surface with a diameter of the basis 12 mm and height 15 mm. The quality of working surfaces was provided not lower than \(R_a 2,5\).
As the experiments have shown, the received roughness depended on a mode of burning of the discharge on a processed surface which was defined by the pressure in the chamber \( p \), current \( I \) and processing time \( \tau \).

**Figure 3.** Minimum roughness surface obtained by the vacuum arc method: a – optical zoom x8, b – optical zoom x56.

In Figure 3 and Figure 4 the photos of conic titanic samples with characteristic results of processing of their surfaces are presented. The minimum roughness \( (R_a < 10 \mu m) \) has been received in a mode: \( p = (1.5 – 3.0)10^{-2} \) mm Hg, \( I = 7 – 9 \) A, \( U = 21 – 23 \) V, \( \tau \approx 20 \) s (6 impulses duration on 2 – 4 s). The maximum roughness \( (R_a > 10 \mu m) \) has been reached in a mode: \( p = 910^{-3} – 310^{-2} \) mm Hg, \( I = 20 – 25 \) A, \( U = 20 – 21 \) V, \( \tau = 75 \) s.

**Figure 4.** Maximum roughness surface obtained by the vacuum arc method: a – optical zoom x8, b – optical zoom x56.

In Figure 5 the results of measurements of a roughness on a reference technique of definition of a \( R_a \) index received on the «Profilometr 296» device (a range of measurements 0,02 – 10 \( \mu m \), the price of division of a scale 0,004 \( \mu m \), a class of accuracy 2) for conic and cylindrical samples are presented.

Characteristic oscillograms of a current and voltage of the discharge for modes with small (Figure 6) and big (Figure 7) roughness are presented below.
4. Conclusion

The method of reception of an adjustable roughness on metal surfaces by electrothermal action of mobile cathodic stains in the vacuum arc discharge is offered. Results of processing of various surfaces under the form by means of the given method are presented.

The main advantages of the method are:

‒ maintenance of a blanket roughness of the basic material of a product;
‒ possibility of the reception of a homogeneous rough surface of a product with a complex configuration (screw, hollow, frame) owing to a specific character of movement of the cathodic stains getting on remote sites of a surface.

Electrothermal action of the cathodic stains in addition clears a surface from various pollutions.
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