

Hardening of the surface plasma jet high-frequency induction discharge of low pressure

N F Kashapov and S N Sharifullin

Kazan Federal University, 420008, Kremlyovskaya str., Kazan, Russia

E-mail: Saidchist@mail.ru

Abstract. The work presents results of research on the hardening surfaces of the products and increase their roughness class of plasma jet of high-frequency induction discharge of low pressure. It is shown that such processing allows to clear at the same time a surface of all types of pollution, to remove a defective layer after its machining, to receive a uniform microstructure, to raise a roughness class on 2 – 3 units.

1. Introduction

There is art, where hardness and surface roughness class products are fundamental determinants of its technical characteristics. For example, in shipbuilding and aircraft such characteristics are the weight of the vessel and its aerodynamics. From them, depend primarily on the tactical and technical properties of this type of machine. Available conventional processing techniques do not allow to obtain higher surface roughness grade 12 and thus not increase its hardness. Therefore, as of today, they can not meet the challenge of competitive products on the world market. There need innovative approaches and use of unusual and breakthrough technologies. These technologies can be only high technology that can produce high-quality products, promising new materials, coatings and surfaces with unusual properties. These include plasma gas discharge technology.

2. Materials and Methods of Research

The technique of gas discharge is used in atmospheric and low pressures. Low-pressure discharge differs from the discharge of atmospheric pressure spike of the average kinetic energy of charged particles in the direction of increasing, especially energy electrons. By blowing a gas discharge plasma gas obtain plasma jet, the average temperature of which may be only a few hundred degrees Celsius, while the electrons – a few tens of thousands. Depending on the method of preparation of the discharge plasma are distinguished as the plasma arc, spark, corona, glow, microwave and RF discharge. Respectively called and apparatus for producing discharges. Plasma gas can be any gas, as inert and aggressive.

A wide range of energy, thermal and gas-dynamic characteristics of low-temperature gas-discharge plasma allows its use in a variety of technologies [1-4]. In this case, the thermal power of the plasma jet can be varied from tens of watts to tens of megawatts, the temperature – from several hundred degrees to 50 000 °C, the effective efficiency Heating may be up to 90%, of the plasma jet velocity - 1000 m/s, continuous operation – up to 1000 hours [5].

The surface microstructure of samples before and after treatment HFI-flow low-pressure plasma was investigated in an electron microscope UEMV-100A. The microhardness of the surface is determined by the PMT-3. Measurements of light scattering glass samples were performed on non-



standard measurement of the scattering laser system LUIR based on a comparison of scattering coefficients of samples and the reference plate. Radiation resistance surface samples was determined on a special stand with a laser LTI-5.

3. Results and discussion

In our case, the choice of the form of the plasma to perform this task, you must meet the following requirements:

1. The plasma must be gas-discharge;
2. The plasma must be clean, ie. E. Products without erosion of the electrodes;
3. Under the influence of temperature of the plasma should not change the basic physical and Mechanical properties of the material of the workpiece;
4. to a plasma properties of the surface layer of the items should significantly change in the direction of improving the quality;
5. To remove the products of processing to use the plasma jet.

Analysis of the plasma properties and possibilities of its application is shown that these requirements can be satisfied high-frequency induction discharge (HFI), low-pressure inert gas stream Fig. 1 [6–20].

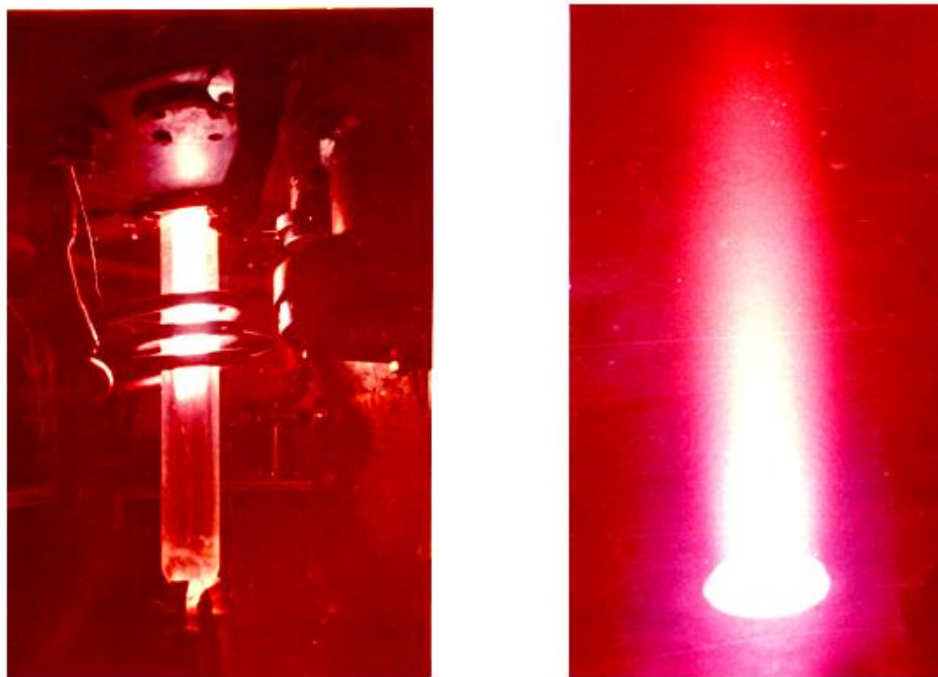


Figure 1. Photographs HFI-discharge (a) and the plasma jet (B) at low pressure

Studies have allowed to define treatment regimens HFI-low pressure plasma for the task. Were treated surfaces of materials of aluminum, titanium, steel, copper and glass of different brands. Below we present some results of the research. Fig. 2 shows photographs of the surface microstructure K8 glass before and after treatment with the HFI-flow low-pressure plasma produced by an electron microscope UEMV-100A. Comparison of the photographs shows that the existing micro-defects surface after plasma treatment are disappearing and formed a brand new, smoother, more uniform surface microstructure. The analysis of these images and the results of other studies led to the conclusion that during processing high frequency induction plasma samples of low pressure is removed the defective surface layer and its subsequent polishing. We point out that the surface roughness of the samples to the plasma treatment is equal to 10 – 11-th class. After treatment reaches

13 – 14 grade surface roughness. Note that the table class roughness on GOST finishes 14th class. It is theoretically achievable roughness class. In practice, existing processing methods do not enable the achievement of higher roughness class 12th.

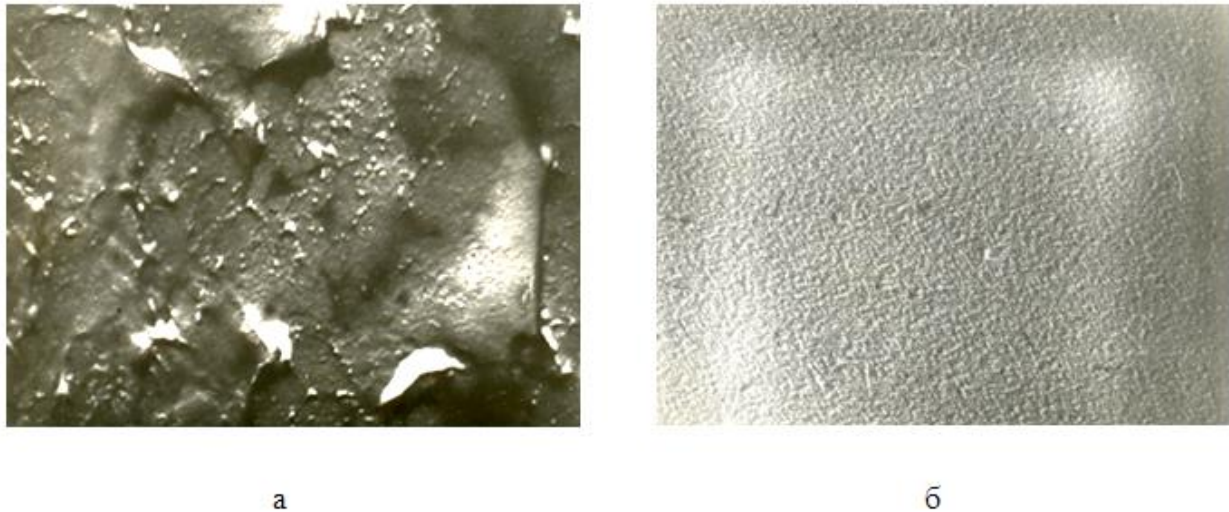


Figure 2. Photos surface microstructures K8 glass before (left lane) and after (right lane) processing flow HFI-low-pressure plasma (x20 000 in the format of A4 paper, photo width corresponds to 4 micron of the surface)

Carrying out the surface treatment of the samples of aluminum, titanium, steel and copper, obtained similar results as that for glass materials. Consequently, no matter what material is manufactured item. The effect is the same. If only the material parts withstand temperatures of 100 - 200 °C. As an example, Fig. 3 shows photographs of a microstructure of the sample surface of the titanium alloy VT6 before and after treatment with HFI low pressure plasma. They show that after plasma treatment on the surface of the material is practically no traces of machining, and dramatically increased its class roughness.

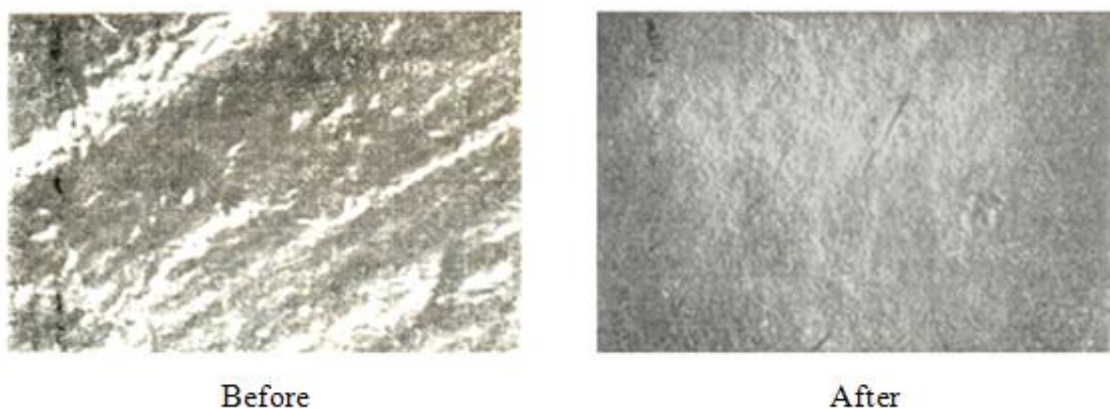


Figure 3. Photographs of microstructures of the titanium alloy BT6 before and after treatment with the HFI-flow low-pressure plasma (x20 000 in the format of an A4 page)

Studies have shown that exposure to a plasma of metals other than cleaning and polishing the surface, and can significantly alter the properties of the surface layer. Measurements of the PMT-3 showed that the HFI-plasma treatment under low pressure leads to an increase in the microhardness of the surface.

For example, the sample of aluminum alloy D16T it rose from 520 to 1140 MPa, steel Article 45 – from 2500 to 5000 MPa and a titanium alloy VT6 – from 2600 to 4600 MPa. Interesting is the fact that under normal conditions of storage within two months of the above material D16T led to an increase in its microhardness up to 1500 MPa. One must assume that under the influence of the plasma flow structural changes occur in the surface layer of the metal, the ordering of structural cells, burn-in and as a result its hardening. The result is a modified surface layer having high hardness, homogeneous microstructure and high grade roughness.

With respect to the defective surface layer. Whenever the machining of pieces in the surface layer of introduced kinds of pollution dust, adsorbed gases, water vapor, oil, particulates chips, abrasive particles, polishing paste, etc.. Pr. Same dirt remain in the surface roughness after machining. It is known that as a result of machining the surface of a so-called defect layer [8]. It is a surface layer consisting of a rough layer and microcracks. The depth of the defect layer during rough machining may be up to 50 microns. Roughened layer is about a quarter of the total thickness of the defect layer. Complete removal of the defect layer surface of the part of any, even the fine machining, is impossible, since she will leave behind a defect layer.

In order to ensure the removal of the defect layer and the surface roughness decrease its exposure to the plasma, were investigated by measuring the light scattering coefficient and the radiation resistance of optical glass surfaces before and after treatment with the HFI-flow low-pressure plasma. By passing a light beam through the glass core energy loss depends on the dirt and the roughness of its surface. Therefore, these numerical parameters will specifically describe the effect of plasma on the surface of the material.

Light-scattering measurements were carried out on a non-standard installation of laser scattering measurement LUIR based on a comparison of the scattering coefficients of the samples and the reference plate. Scattering was determined at a wavelength of 632.8 nm in the «S» - polarized laser radiation. Index «S» means the polarization when the electric vector is perpendicular to the plane of incidence. The results of measurements of the scattering coefficient for the 14 glasses K8 showed that HFI-plasma treatment at low pressures allows reducing 2-3 times the scattering coefficient of glass.

Radiation strength surface samples was determined on a special stand with a laser LTI-5. Measurements have shown that after the HFI-plasma treatment the radiation resistance of the surfaces of glass K8 increased by 1.5 – 2 times. The decrease in light scattering coefficient of optical glasses is 2 – 3 times after the HFI-plasma treatment of their surfaces, with a simultaneous increase in the radiation resistance of 1.5 – 2, is convincing proof removal of defective surface layer and increase its roughness class.

JavaScript removal of defective surface layer HFI plasma treatment can be used to increase the transparency of glass cockpit fighter with a simultaneous decrease in the angle of inclination. This in turn will improve the aerodynamic characteristics of the aircraft.

By varying the length of the surface treatment, it is possible to explore the process of changing the microstructure. Fig. 4 shows photographs of the microstructures of the sapphire surface at different durations of treatment. Comparison of the photographs shows that plasma

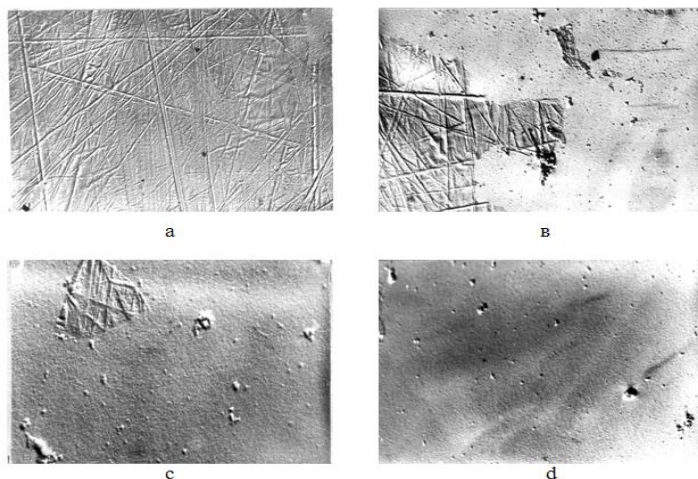


Figure 4. Changes in the microstructure of the sapphire surface, depending on the duration of treatment HFI-plasma (x20 000 in the format of an A4 page)

treatment at first there is the fragmentation of large micro defects into smaller and then removing them from the surface of the plasma stream. Processing occurs due to bombardment of the surface by ions, electrons, excited atoms, photons, and as a result of mechanical and thermal effects of the HFI-plasma flow, ie surface of the sample is under the influence of a complex energy, thermal and the gas-dynamic parameters of the plasma flow. Studies have shown that the surface treatment of the HFI-plasma subject to any details.

4. Conclusions

Analysis of the results for the HFI-plasma surface treatment of parts made of different materials allows us to conclude that there is a new tool for modifying a thin surface layer of the part. It can simultaneously clean the surface of all types of contaminants to remove a defective layer after the machining to obtain a uniform microstructure, and to increase the microhardness of 1.5 – 2 times.

References

- [1] Galyautdinov R T, Kasparov N F and Luchkin G S 2002 *Inzhenerno-Fizicheskii Zhurnal* **75** 170–173
- [2] Fadeev S A, Kashapov N F and Larionov V M 2014 *IOP Conf. Ser.: Mater. Sci. Eng.* **69** 012006
- [3] Fadeev S A and Kashapov N F 2013 *J. Phys.: Conf. Series* **479** 012009
- [4] Kashapov N F, Saifutdinov A I and Fadeev S A 2014 *J. Phys.: Conf. Series* **567** 012004
- [5] Dautov G Y, Dziuba V L and Karp I N 1984 *Plasma torches with stabilized arcs* (Kiev, Naukova Dumka) 168 p
- [6] Sharifullin S N 1977 *Research and application of some high-frequency low-pressure discharge. (Diss. cand. tehn. Sciences)* (Kazan) 198 p
- [7] Kashapov N F 2001 *Inkjet RF plasma torches during the coating process under dynamic vacuum. (Diss. Doctor. tehn. Sciences)* (Kazan) 506 p
- [8] Israfilov I H, Samigullin A A, Sharifullin S N and etc. 1976 *The energy characteristics of high-frequency plasma unit at low pressure (Physics and Chemistry of Materials Processing, # 3)* Pp 26-31
- [9] Gainutdinov I S, Dautov G Y, Samigullin A A, Sharifullin S N, Shcherbakov V D 1977 *Cleaning and polishing of substrate surfaces high frequency induction plasma of low pressure (Physics and Chemistry of Materials Processing, # 6)* Pp 150-152
- [10] Abdullin I Sh, Kashapov N F and Kudinov V V 2000 *Changes in the structure and composition of the surface of steel and titanium alloys under the influence of high-frequency low-pressure discharge (International scientific journal "Advanced Materials", # 1)* Pp 56-60
- [11] Abdullin I Sh and Kashapov N F 2000 *Modification of steels and titanium alloys by means of high-frequency low pressure plasma (Preprint, KSTU)* 16 p
- [12] Abdullin I Sh and Kashapov N F 2000 *Preparation of surfaces of metals, dielectrics and semiconductors to the coating by means of non-equilibrium low pressure RF plasma (Preprint, KSTU)* 16 p
- [13] Abdullin I Sh, Kashapov N F and Kudinov V V 2000 *Treatment of inorganic materials nonequilibrium low-temperature plasma before coating (International scientific journal "Advanced Materials", # 3)* Pp 88-94
- [14] Kashapov N F 2000 *Changes in the structure and composition of the surface of steels and titanium alloys after exposure to low temperature plasma reduced pressure (Hands. Depon. in ONTI union VINITI, # 973) (V00, KRTU, Kazan)*
- [15] Denisov E S, Temyanov B K, Sagdiev R K and Fazlyyyakhmatov M G 2014 *IOP Conf. Ser.: Material Science and Engineering* **69** (1) 012014

- [16] Abdullin I Sh, Sharifullin S N, Shcherbakov V D and Vdovin D A 1979 *Treatment of metal surfaces induction plasma flow (Low-temperature plasma: Intercollege. Sat.)* (Kazan: KAI) Pp 55-58
- [17] Abdullin I Sh, Sharifullin S N et al. 1981 *Study changes in the surface properties of the titanium alloy under the influence of the induction plasma diffuse discharge (Low-temperature plasma: Intercollege. Sat.)* (Kazan: KAI) Pp 18-22
- [18] Sagdiev R K, Denisov E S, Evdokimov Yu K, Fazlyyyakhmatov M G and Kashapov N F 2014 *IOP Conf. Ser.: Material Science and Engineering* **69** (1) 012012
- [19] Sharifullin S N 2014 *Hardening of surfaces of products and increasing their roughness class of low-temperature plasma jet (Abstracts of the II International scientific and practical conference "Perspective materials and technologies for production" in the framework of the International Forum "Crimea Hi-Tech - 2014")* (Sevastopol, 22-28 September 2014. M.: NUST "MISA") Pp 282-288
- [20] Sharifullin S N 2009 *Improved operational reliability high pressure fuel pumps automotive diesel engines (Diss. Doctor. techn. Sciences)* (Moscow) 368 p