THE ACTION OF ELECTRICAL DISCHARGES IN IMPULSE PLASMA ON STRUCTURE AND PROPERTIES OF STEEL 45 SURFACE STRATA

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INTRODUCTION

It is known that pieces used in machine and equipment building often function in condition of mechanical wear, under wide range of temperatures, in aggressive media from chemical point of view etc. These specific operating conditions of modern technology impose special requirements on durability and reliability of the whole construction and of their constituents separately.

A new technology always has a value to human society if it meets the following criteria: practical applicability, the financial economy, reliability and performance. Obtaining special properties of surfaces with nanometer thin films is the tendency of contemporary strategic research by developing new proceedings and material processing technologies, thus ensuring high productivity and material economy and ensuring high quality of products.

There exists and develops more and more fierce concurrence between traditional and non-conventional material processing on the global market of technics and technology. Favor is on side of new technology, which actually intended to annihilate material and energy crisis that swept around the world.

Electrical discharges in impulse as concentrated sources of energy increasingly find applicability in non-conventional materials processing technology in order to modify structure and properties of superficial strata of machine building pieces. With help of this technology we can achieve surfaces with high thermal and electronic emission properties, hardened surfaces, surfaces with anti-corrosion properties, surfaces with increased electrical surface resistance, surfaces with anti-sticking and anti-friction properties, surfaces with anti-wear properties, etc.

The aim of present investigations consists in analysis of the action of electrical discharges in impulse plasma on the structure and properties of steel 45 surface strata.

1. METHODOLOGY OF EXPERIMENTAL INVESTIGATIONS

Cylindrical steel 45 samples were made as electrodes for experimental investigations. Working surface of the samples was grinded and polished up to "mirror" surface for more qualitative analysis of the processed surfaces. The electrodes were fixed into the interstice establishing device so that the working surfaces of the anode and cathode are parallel to each other.

As a source of energy was used current impulse generator that includes the following electrical blocks (Figure 1): power impulse generator, starter block destined for electrical discharge initiation and command block whose role is to synchronize power with starter block impulses.

As it is shown in the figure power impulse generator consists of autotransformer (T1) power transformer (T2), rectifier (D1-4) ballast resistance (R1), capacitors (C1-C4); switches (k1-k4); block of diodes (D5), thyristor (D7).

Starter block contains the following elements: transformer (T4), rectifier (D9-12), capacity (C5), thyristor (D8), high voltage transformer (T3).

The command block allows performing not only the synchronization impulses, but changing the working frequency of the generator too.

The functional principle of the generator which electrical scheme is shown in Figure 1 is based on accumulating a quantity of electrical energy in condenser battery and its discharging in form of a short term (τ = 200-250 μs) impulse.

Capacities (C1, C2, C3, C4), depending on the position of switches (K1-4), are powered through the charging impedance (R1) out of a DC source, which consists of autotransformer (T1), power transformer (T2) and rectifier (D1-4).

Autotransformer (T1) allows fine tuning of the operating voltage and supplies the impulse generator.

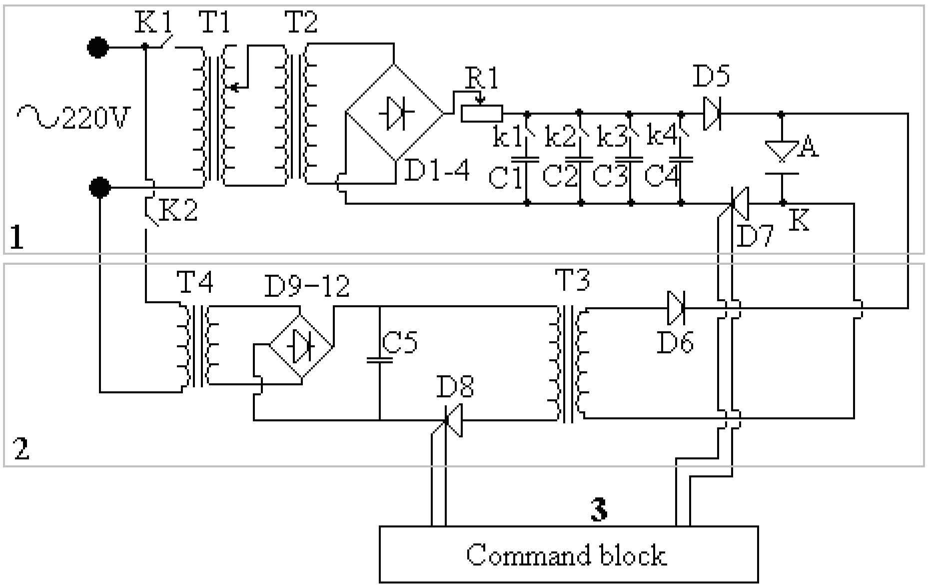


Figure 1. Principal electrical scheme of the impulse generator:
1 – power impulse generator; 2 – starter block; 3 – command block.

Block of diodes (D5) is designed to protect generator of the high voltage impulse entering into it.

Resistance (R1) has the function of charging current limitation, which prevents the conversion of electrical discharge in impulse to electrical discharge in arc.

The charging of the capacitors (C1-C4) and (C5) takes place in the process of installation functioning simultaneously.

The command block sends a signal that causes opening of the thyristor (D8). Because of this, capacity (C5) is discharged through the primary coil of high voltage transformer (T3) and the electrical current begins to move through it. This electrical current causes the appearance of high electric voltage (striking voltage) in the secondary coil terminals, which are joined respectively with anode and cathode of the experimental installation. Due to high voltage, striking of the interstice and formation of conductible canal take place.

At the same time, the command block emits another signal that causes the opening of the thyristor (D7) and discharging of the capacitors (C1-C4), with formation of the basic impulse. After that, the process repeats again.

The phase shift of thyristor (D7) and (D8) opening moments is very small and can be adjusted within the large limits, by the command block.

Starter block allows preventive ionization of the interstice with high-voltage impulse of 12 kV and 0.3 μA current value. Impulse forms of the power generator and the starter block is shown in Figure 2.

Processing is performed in sub-excited regime, i.e. when the energy released on the sample surfaces does not reach values necessary for melting the processing surface layer. Energy balance condition in this case is:

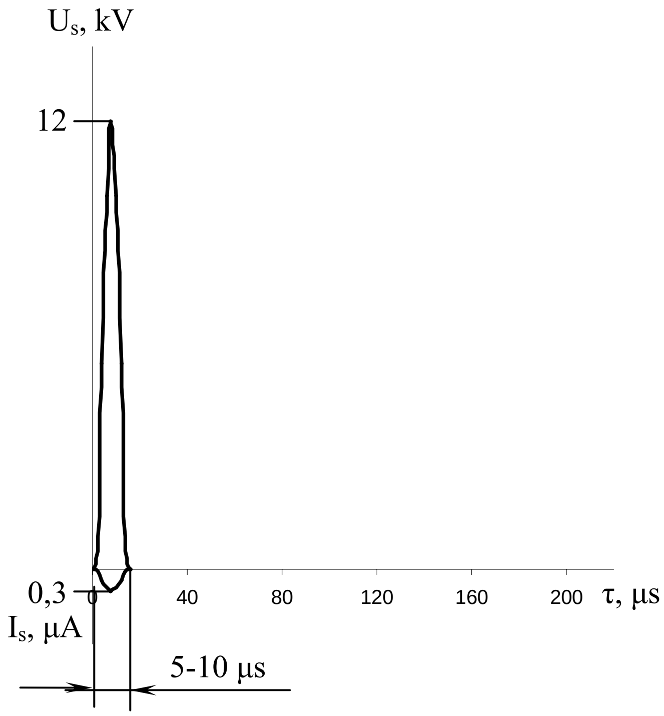
$$Q = \frac{4W_S}{\pi d_c^2 S} < Q_{melt}, \qquad (1)$$

where $W_S = \int_0^\tau u(t)i(t)dt$ is amount of energy released in the interstice; u(t) is voltage drop in the interstice; i(t) is momentary value of current in the interstice; τ is impulse duration; d_c is diameter of the plasma canal; S is the interstice value; $Q_{melt} = q_{melt} \cdot \rho$ is melting volume density of the workpiece; q_{melt} is specific melting heat of the workpiece material (for steel 45 - q_{melt} = 84kJ/kg); ρ is material density at the melting temperature (for steel 45 at its melting temperature T_{melt} = 1500ºC density ρ = 6900 kg/m^3).

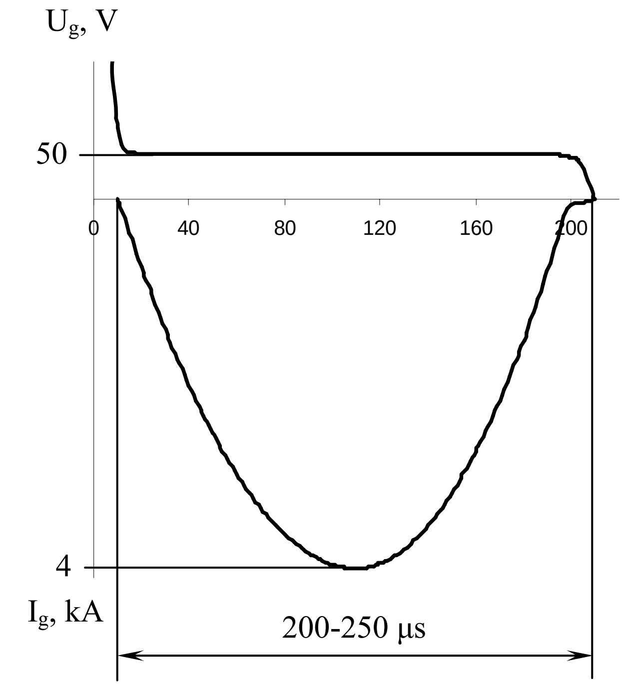
Then the amount of heat released in a volume of surface: Q < 579,6 MJ/m^3.

For example, for distance between electrodes S = 1.5 mm, the diameter of the plasma canal dc ≈ 3-4 mm (approximately is equal to the width of the strip determined by the authors [4]) and the energy released in the interstice W_s < 6-10 J.

The value of energy released in the interstice in limits W_s = 0,4-4 J corresponds to values of the charging voltage of condenser battery U_c = 100-200 V and capacities C = 100-600 μF of the impulse generator. This satisfies the above condition.



a)



b)

Figure 2. Variation of current intensity and voltage respectively:
a) of an impulse of the starter block;
b) of an impulse of the power generator

2. RESULTS OF INVESTIGATIONS AND THEIR ANALISIS

The phenomena of micro-tempering (Fe-γ appearance in the surface layers) and formation of iron oxides and hydroxides in amorphous state is attested during the machining of plane piece surfaces made of steel 45 by applying electrical discharges in impulse in ordinary conditions in regime of "cold" electrode spots (without appearance of liquid phase). It is confirmed by the results of quantitative and qualitative analysis of the machined surfaces (Figure 3-5).

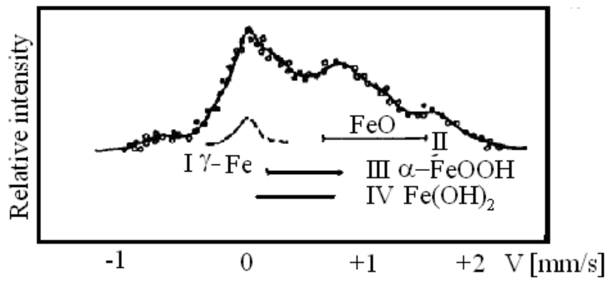


Figure 3. Mössbauer spectroscopy of steel 45 sample surfaces machined by applying electrical discharges in impulse [1, 2].

The amount of oxygen dissolved in the surface piece layer made of steel 45 range from about 60 at the workpiece surface until about 20 at 240 nm depths. This phenomenon can be explained based on the diffusion, micrometallurgical and electrochemical processes that produce in the material of the workpiece under the action of electrical discharge in impulse plasma.

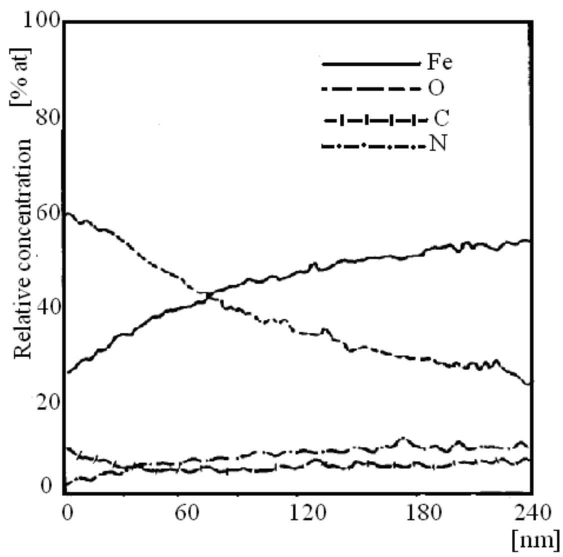


Figure 4. Concentration elements distribution in steel 45 surface strata after machining by applying electrical discharges in impulse [1, 2].

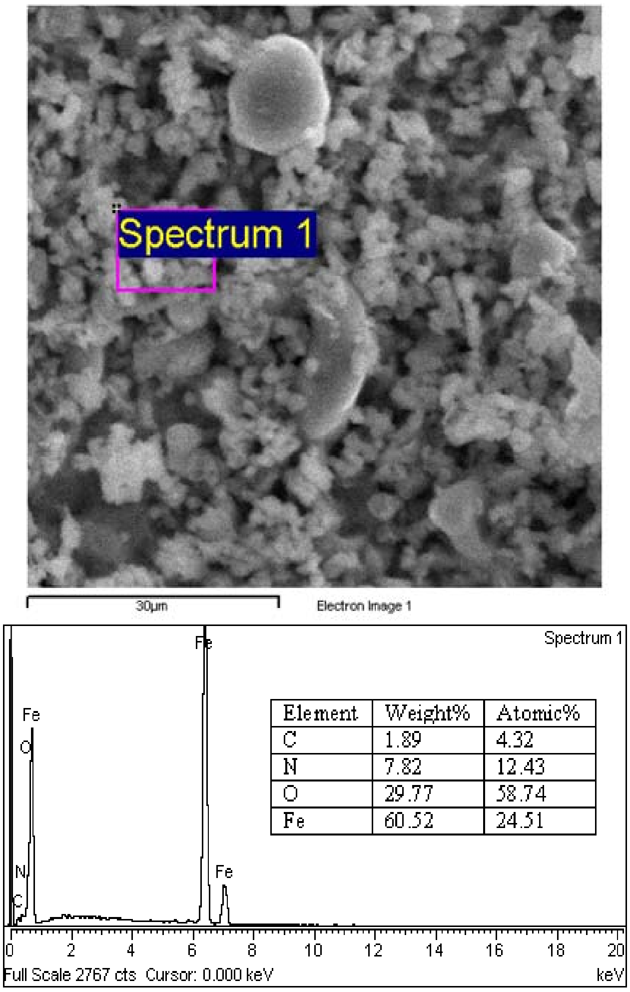


Figure 5. Spectrogram of steel 45 samples after machining by applying electrical discharges in impulse (electronic microscopy TESCAN, ×1000).

Detailed research on surface electrical resistance and resistance to corrosion of pellicles formed on steel surfaces 45 with electrical discharges in impulse [3, 4] have shown that, due to the formation of oxides and hydroxides in the amorphous state, the surface electrical resistance of the samples increased from hundredths of Ω until ~1 MΩ, resistance to corrosion has increased in about 2 times. Due to simplicity of technology and lower costs of electricity, the formation of oxides and hydroxides pellicles using electrical discharges in impulse can be successfully applied in manufacturing of resistors for microelectronics and radiotechnics and in corrosion protection of drinking water pipes. Experimental investigations demonstrate that microoxidation processes occur simultaneously on the surface of the tool-electrode too, but they proceeded with an intensity of about three times lower than for the workpiece. Electrode-tool surface oxidation and erosion cause breach of the workpiece surface processing technology, that is why the special conditions required for their elaboration. During the machining of the rotary surfaces and, in a particular case, cylindrical and conical surfaces (exterior or interior) condition of continuous work of the apparatus is to maintain constant the size of the discharge interstice. Therefore, it is proposed to manufacture electrode-tools with conjugated to the workpiece surface configuration and their coaxial positioning in relation to the processing surface. At the same time, it is required that their active part mast be manufactured of a less active material to oxidation.

3. CONCLUSIONS

Based on the results of personal experimental research and to those obtained by other researchers we can conclude the following:

- a considerable amount of oxygen is dissolved in steel 45 piece surfaces under the action of electric discharges in impulse plasma;

- the processes of structure and chemical composition modifying of piece material occur in the machined surface;

-oxide and hydroxide pellicles formed by applying electrical discharges in impulse can be successfully applied to increase active electrical surface resistance and resistance to corrosion of pieces in machine and apparatus building.

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