IMPROVEMENT OF COATING QUALITY OBTAINED BY ELECTROSPARK ALLOYING WITH NONABRASIVE ULTRASONIC FINISHING POLISHING

E.A. Ledkov¹, V.M. Davydov¹, S.N. Khimukhin¹, A.V. Gil¹
1. Pacific National University, Khabarovsk, Russian Federation

ABSTRACT
The present paper deals with the formation and improvement of microrelief of surfaces obtained by electro spark alloying (ESA) within the study on the control, prognostication and automation of the ESA process.

KEYWORDS: ESA, roughness, surface microrelief, coating.

1. INTRODUCTION
The ESA rests on the use of erosion destruction of the anode material (a processing electrode) and subsequent transfer to the cathode (a part). In this case a metal layer is formed on the part surface with changed compositions and features often different from the initial ones. The merits of the process are the following ones: the potential in coating of the machined surface of current-conducting materials, high connection of the applied layer to the foundation, low energy capacity of the process, an easy conduction of technological operations, etc. Among major features of the layer are: the applied layer thickness, micro hardness, coating continuity, porosity, etc. But there are some shortages of the method preventing it from being widely used in production. Among essential shortages are high surface roughness and cracks in the layer since as a result of machining roughness becomes so substantial that it constraints its use, while residual stresses induce cracks, rising layer brittleness and reducing its quality. Currently the problems are solved by diamond burnishing, polishing, and grinding, leading to the change in the layer features. So the aim of the present work was the study of the formation of the surface layer micro relief and its quality improvement, which was formed at ESA on the part.

2. EXPERIMENT
Commercially fabricated setups “Elitron 22A”, “Elitron 52B”, and “UR–121” were used in experiments. Copper, low-carbon steel, and hard alloy VK6-OM were applied as the anode material, which were put on the cathode from high speed steel P6M6 and low-carbon steel. The initial roughness was $R_a = 0.2 \mu m$. Such a selection of electrodes materials is explained by their wide use in machine building. Roughness was measured with Abris PM-7 type profilometer after each minute of machining. The following roughness parameters were considered: $R_a$, $R_z$, mean roughness spacing $S_m$, maximum profile heightness $R_{max}$ and surface profilograms. To improve the layer quality these were machined with a device of nonabrasive ultrasonic finishing machining. The formation mechanism of the layer microrelief was studied on the setup “Elitron 52B” in a mode of resistance-capacitance current source ($I = 30-130 \, A$, $U=430-60 \, V$, capacity 480-2040 $\mu F$).

3. RESULTS AND DISCUSSION
3.1 Micro relief dependence oh the machining time, setup power, and cathode and anode materials
As is known, surface microrelief or roughness is a set of surface irregularities with relatively
small asperities at the reference length which is measured in micrometers (µm). Roughness dictates the most important performance characteristics of solids, and, above all, wear-resistance from abrasion, joint tightness, chemical resistance, and appearance. Roughness at the ESA is currently thought to be dependent, in a direct way, on a reduced energy of impulses, namely, the larger the reduced energy the higher roughness. Many similar dependencies have been obtained throughout the world, but few of them consider that the microrelief formation is a complex and essentially nonlinear process. It cannot be assessed by statistical methods, as are conventionally used for machined surfaces. Roughness of a surface machined by electro spark machining (ESM) is close to irregular roughness [2], which is shown in Figure 1. Additionally, it is not convenient to use the reduced energy since it depends on too many factors and is not constant per unit time [3]. In our opinion, the most convenient parameter in considering dynamics of the roughness formation is time with indication of a specific machining mode and a setup used.

Figure 1: Profilogram.

Depicted in Figure 2 are plots for the arithmetical mean deviation of the layer profile by the ESA as a function of time for various materials and setups. Each point in the plot is a mean value of roughness in \( R_a \) (three measurements at a minimum) per square centimeter.

Figure 2: Rough edges as a function of time for various materials and setups.
In the first minutes a drastic increase of all measured roughness parameters is observed, which is due to the electrode running-in and intense mass transfer. However, roughness does not become stable with time, as is conventionally thought, but starts to oscillate for an infinite period of time. In our opinion this is due to the replacement of direct with reverse mass transfer and vice versa. The magnitudes of roughness parameters are believed dependent on the setup power and an amount of the reduced energy, which is not quite so. Roughness is conditioned on the energy of the initial pulse since just the unit pulse dictates the drop size of a melted metal, and, consequently, microasperity height. The unit pulse energy is time-varying and distinct from the pulse energy at the generator exit. It depends on many factors such as material, ambient medium, machining time, etc.

It is important to note that the roughness parameters present statistical quantities (for instance, arithmetical mean deviation of the profile), devised and successfully used for surfaces obtained by machining, casting, etc. But at the ESA the scatter of values for the \( R_a \) parameter per unit square of a machined surface is that large that it can hardly be used (Figure 3). In our experiments the \( R_a \) values measured for 1 cm\(^2\) varied from 3 to 10\( \mu \)m. It follows that the mean value cannot be thought as reliable.

3.2 Formation of surface micro relief at the ESA

The appearance of a surface after ESM in air (gases) is dramatically different from that after machining. Figure 4 presents a model of surface profile formation at ESA. The necessary condition for ESA is a contact between electrodes which occurs between the most protruding parts of the anode and cathode. After the circuit is closed the discharge of capacitors of a pulse generator occurs. The electric current through the contact heats up the anode and cathode. Once a specific temperature is reached the explosion occurs, and the heated metal undergoes a transition into plasma. A melted metal drop goes from the anode to cathode, cools to form a layer of changed structure. Important in this case is the fact that mass transfer occurs dominantly in the places the most protruding above the mean profile line (Figure 4, steps 4-6). Figure 5 depicts the result of a long time machining. The given sample was obtained with the “Eltron 52B” setup at regimes of a high power (RC) and makes it possible to observe the surface micro structure formation at macro levels. In considering coating over large area it is not appropriate to judge roughness in the usual sense in view of its instability. To evaluate the profile quality at an area greater than 2 cm\(^2\) we propose to use the common term “undulation”. Undulation takes an intermediate place between the shape deviations and the surface roughness and makes it possible to judge the surface relief in a precise manner.

Figure 3: Scatter of roughness values
Figure 4: Model of formation and improvement of microrelief at ESA

Figure 5: Surface relief obtained by ESA on the Eltron 52B setup (anode – Cu, cathode – high speed steel).
3.3. Improvement of the surface relief quality after the ESA

To improve the quality of the surface micro profile after ESA a number of ways are used. However, most of them rest on the removal of a part of the layer by a mechanical way (polishing, grinding, diamond burnishing). As a result the surface relief becomes the following (Fig.4, steps 7-9). The layer relief is composed of bearing surfaces and cavities; the latter presents micro pockets (MPs), which are able to keep oil at rest and in motion. With MP increasing the lubricant volume is also increased, that is tribotechnical characteristics improve. In this case, however, the bearing area in the contact is decreased, reducing rigidity characteristics of the contact and its carrying capacity /1/. Also, residual tensile stresses occur in the surface layer, which bring about cracks and make the coat more brittle.

To overcome this problem one should use nonabrasive ultrasonic finishing machining (NAUFM), which has been designed in the North-West Center for Ultrasound Technologies. The method does not require abrasives or cutting tools. Instead the impact force of ultrasound is used which makes the micro asperity tips flatter. This technology, as applied to ESA, makes it possible to reduce roughness of a machined surface from 12.5 0.2 µm without removing part of the layer. Additionally, in this case further surface hardening takes place. Of note is the fact that one can solve using NAUFM the challenge of tensile stresses arising at ESA since compressive stresses appearing at NAUFM compensate for tensile stresses. Surface microsections obtained by NAUFM after ESA are shown in Figure 6.

![Image](image.png)

**Figure 6:** Running-in of NAUFM after ESA (anode – Cu, cathode – steel).

4. CONCLUSIONS

Investigation results are:

1. Regularities in variation of surface micro profile (roughness), obtained by the ESA, as a function of time are established for various materials and setups.
2. A novel approach to an estimation of the profile quality of the surface machined by the ESA is designed.
3. On the basis of an analysis of currently used running-in operations for surfaces obtained by the ESA technological recommendations on the improvement of their micro profiles are made.
4. Statistical data are collected, which make it possible to consider the surface roughness obtained by the ESA as a component of the expert database of a neural network model for control of electro-spark alloying process.
5. REFERENCES

