# THE SUPERFICIAL LAYER OF PARTS ALLOYED BY ELECTRO-DISCHARGE METHODS

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**Abstract**

Electrical discharge machining is one of the main methods of manufacturing technological equipment used in the foundry industry, plastics processing, plastic working, etc. Important elements determining its quality are, apart from the properties of the materials used, the features imparted in the manufacturing processes. The paper presents a brief study of electro-discharge alloying process of surface with using rod vibrating electrode. It is also economically justified to use EDM (Electrical Discharge Machining) to produce machine parts from materials that are easily machined, but with very complex geometry, and therefore difficult and labor-intensive to produce using conventional methods. Spark discharges are created between the working electrode and the workpiece, the entire process takes place in a working medium with dielectric properties. As a result of the local increase in temperature, melting and partial evaporation of the microvolume of the material occurs. The main factors influencing the formation of the surface layer in the process of its modification are the melting process, diffusion processes, rapid heating and cooling of the material, phase transitions and changes in the structure of the layers adjacent to the crater formation site. In the tested process, the modified surface layer with improved properties reached a thickness of up to 90 micrometers, and the material resolidified on the surface of the workpiece contains about 50% of alloying elements. The geometric structure of the surface resulting from the modification is similar to that obtained by EDM. The distribution of inequality vertices is random. For typical machining conditions, the obtained roughness *Sa* is approximately 3.5 μm.

**Keywords:** Electrical discharge machining (EDM), alloying, surface layer, roughness

## 1. INTRODUCTION

Machine elements operating in conditions of friction, erosive wear, corrosion, etc. should be made of materials with improved properties. Depending on the expected operating conditions, their surfaces should have a surface layer with appropriate properties, e.g. increased content of alloy components, high hardness, specific geometric structure of the surface, etc. In many cases, it is necessary to core has the required plastic features and specific surface areas have e.g. high hardness, resistance to abrasive wear, resistance to thermal effects, etc. [1-3]. It is then necessary to use surface treatment to obtain the desired SL (superficial layer) properties. Using high-alloy materials for entire elements is usually more expensive than producing a local surface layer with specific properties. Currently, surface engineering includes several dozen processing methods ensuring various properties of surface materials including explosive methods [4]. Their detailed analysis and description is contained in many publications [6,7]. The most frequently used methods of modifying surface layers [8,9] include the following treatments: thermal (surface hardening), thermo-chemical (carburizing, nitriding, boriding, etc.), mechanical (burnishing, shot peening, etc.), thermal spray, concentrated energy stream (laser, electron, implantation, electrospark) [8,10].

Most of the mentioned treatments are used to produce SL on the entire surface of the object (thermal, thermo-chemical, mechanical) or require the use of very expensive technological devices, in particular implantation, laser and electron treatment [2]. There are many types of technological devices for electroerosion machining and modification of the chemical composition of surfaces protected by patents. Many publications concern the study and modeling of physical phenomena in the process of unconventional machining [11] and investigations on the basis of the process  or roughness of surface [12].

## 2. ANALYSIS OF FACTORS AFFECTING THE EFFECTS OF STOPPING USING ELECTRIC DISCHARGES

Experimental tests were carried out on an electrical discharge machine. The electrical discharge machine is composed of several mechanical, electrical, electronic, hydraulic and pneumatic components. Computer software and control executive systems are also required to control the machining process. The research used the ROBOFORM 30 machine tool, which includes the components shown on (**Figure 1**):

- work table connected with the processing space,
- a pulse generator supplying the working circuit (inter-electrode gap) with electrical energy with the required characteristics,
- inter-electrode gap regulator,
- dielectric feeding and filtering system,
- a set of servo drives for the machine tool for moving the axes,
- CNC computer control system,
- user interface for communication with the machine tool.

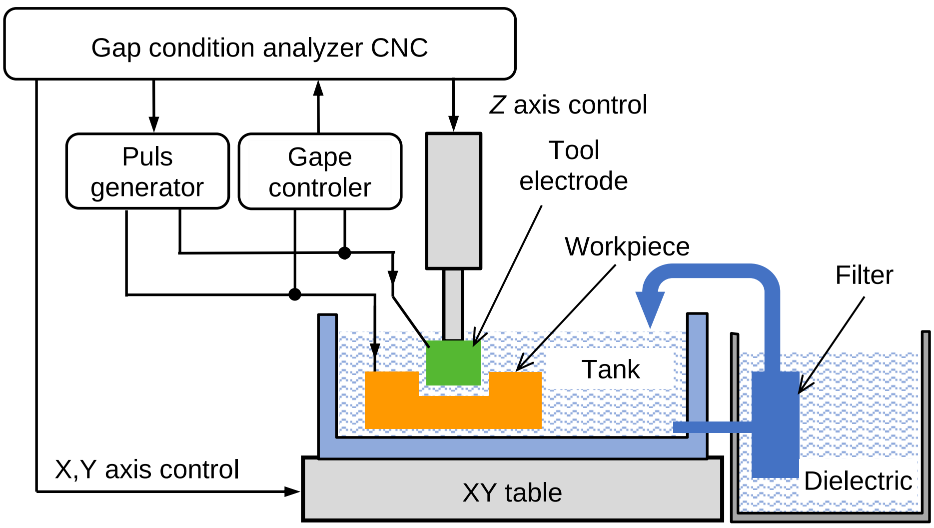



**Figure 1** Scheme of sinking electrical discharge machine

In electrical discharge machining, the main factor influencing the formation of the surface layer are spark discharges [10]. As a result of single discharges, local melting occurs, accompanied by heat and mass exchange in the inter-electrode system. As a result of the described interactions, the chemical composition of the surface layer is modified and craters are created on its surface. Due to the random distribution of the positions of these irregularities and their overlapping, they create a structure of a random nature [1]. Authors [9] analyzed individual fragments of the electrical signals of the inter-electrode system and on this basis recognized the open state, proper discharge, short circuit state and arc discharge. The analysis of the literature and the authors preliminary research allowed for the conclusion that the physical phenomena accompanying electric discharge in the electro-discharge machining process can be used to modify the chemical composition or apply coatings with specific properties to the machined surface. Surface modification, under the described conditions, is preferably carried out using working electrodes with an appropriately selected chemical composition. The process of transferring the material of the working electrode - anode to the surface of the workpiece is called electrical discharge alloying - EDA (Electrical Discharge Alloying). Determining the conditions of mass transfer between electrodes and the effects obtained are important elements of the research work. Assuming idealized shapes of the voltage and current values [9] in the inter-electrode gap as a function of the erosion time *tw*. The energy supplied to the interelectrode gap can be controlled by changing the value of the discharge current *Iw* and the discharge time *tw*. The shape of the current value has a significant impact on the resulting machining parameters (parameters of the geometric structure of the surface, process efficiency). In the electrical discharge machining process, a constant value of the energy of individual pulses from the generator is desirable, because it significantly affects the condition of the surface layer, including the resulting roughness of the workpiece [3, 8].

## 3. RESULTS OF TESTS ON THE EFFECTS OF ELECTROEROSITION ALLOYING

The tests were carried out using C45 steel samples as the substrate. **Figure 2** shows an example photograph of an erosion crater taken using the light microscopy technique on a Nikon Eclipse MA200 microscope. In the presented case, the crater was obtained using a rod electrode with a diameter of d = 0.3 mm.

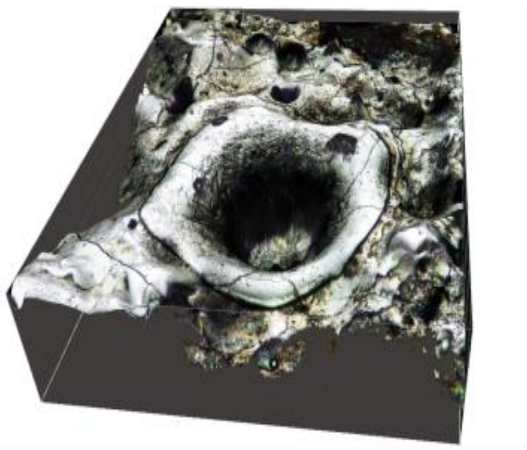


**Figure 2** Microphotograph of a crater - the effect of a single discharge, electrode diameter d = 0.3 mm, Nikon Eclipse MA200 light microscope, magnification 200x

**Figure 3** shows an example height map of the surface after electro-discharge alloying. A detailed analysis of the surface topography indicates that there are no privileged roughness directions on it.

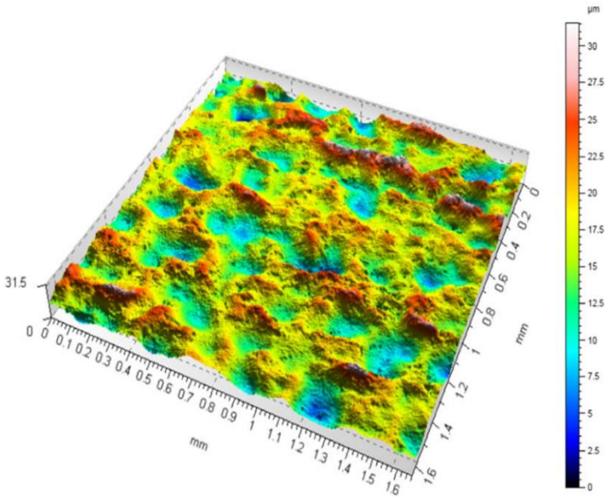
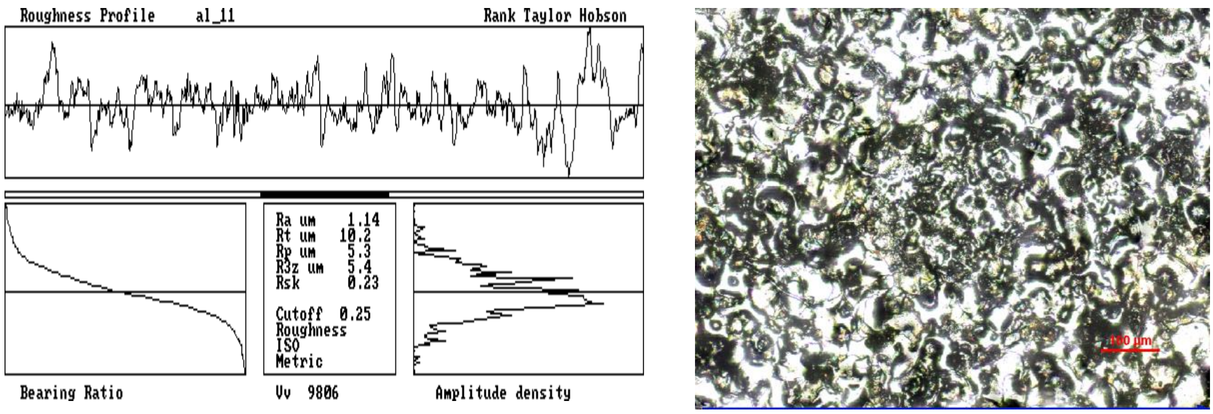



**Figure 3** Sample 3D map of the surface after alloying. The tests were performed using the Talysurf CCI Lite - Taylor Hobson optical profilometer

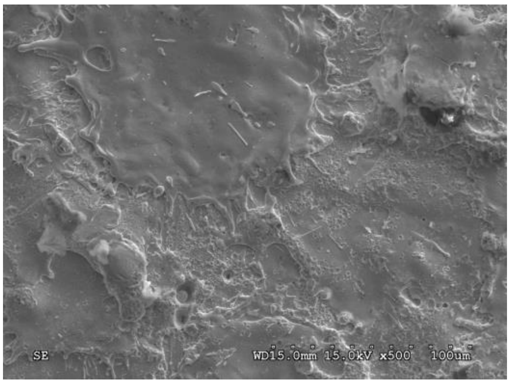
Examples of the surface roughnes and microphotographs SEM of the surface after treatment EDM alloing shown in (**Figure 3**). For typical machining conditions, the obtained roughness *Sa* is approximately 3.5 μm.




a) b)

**Figure 4** Surface topography: a) sample of the surface profilogram, b) microphotographs SEM of the surface after treatment EDM alloing

Examples of the results of the tests performed were documented in the form of photographs of the surface, spectral distribution of elements, mass and atomic fractions of individual elements constituting the alloyed layer, shown in (**Figure 4**). SEM examination was performed using a JEOL JSM 7100F microscope with field emission (Schottky). X–ray diffraction pattern obtained from the surface layer. The exemplary linear distribution of tungsten (**Figure 5**) indicates a significant increase in its content in the surface layer of the alloyed sample. The thickness of the modified layers, depending on the electrical parameters of the process..

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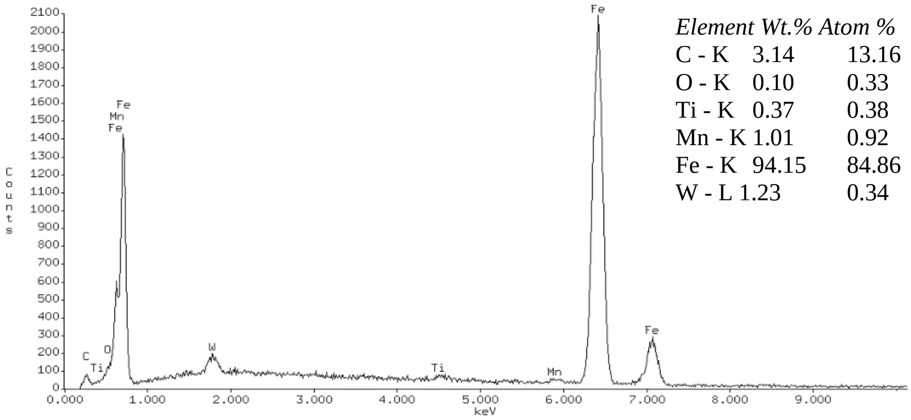
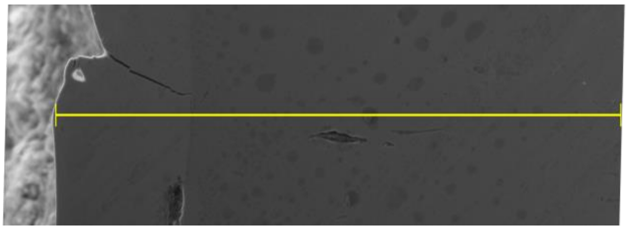



b)

**Figure 5** SEM micrograph (a) of the surface after alloying with a tool electrode made of tungsten carbide, spectral distribution of elements and the results of point X-ray microanalysis of the chemical composition of the surface (b)



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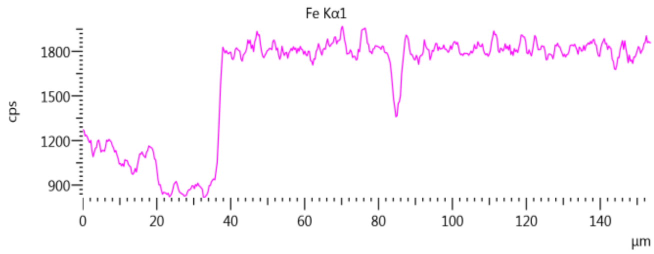


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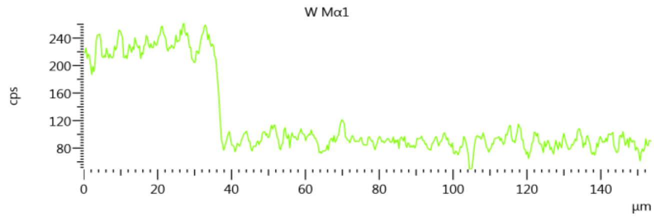


c)

**Figure 6** Photograph of the metallographic microstructure of cross-section of sample - C45 steel electro-discharge alloyed with a tungsten electrode a), linear distribution of iron b) and tungsten c)

## 4. CONCLUSION

1. Alloying causes increasing durability, heat resistance and corrosion resistance;
2. Alloying enables regeneration of tools, mechanisms and machine elements;
3. Carrying out micrometallurgical processes on the treated surface in order to produce the desired intermetallic phases or chemical compounds;
4. As a result of the impact of electrical discharges, it is possible to obtain layers of specific roughness on the surface (surface texturing), e.g. to increase the intensity of heat transfer.

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