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Experimental Investigation of Voltage on White Layer Thickness in EDM Process

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ABSTRACT

Electric Discharge Machining (EDM) is a non-contact and non-conventional tool used in industry for machining hard surfaces and high precision products. After being machined, the EDM process is commonly assessed based on surface roughness and recast layer (the white layer) on the product's surface. The electrical discharge phenomenon has been the subject of numerous investigations and methods, which have been suggested through advancements and process optimization. The thickness of the white layer is one of the most important parameters to consider in the contemporary electrical discharge machining process as it greatly impacts the surface quality of the specimens that are milling with it during the process. White layer development is the primary characteristic of EDM, and it has been examined in the current paper with respect to open circuit voltage. The desired white layer thickness (WLT) is determined by using strict control parameters over the cutting process, such as voltage, wavelength, and other parameters, to ensure uniformity, cracklessness, and white layer thickness in smoothing. The research focuses on the relationship between voltage and the thickness of welded layers (WLT) in AISI 444 stainless steel. The tests showed that WLT increased because the EDM parameters of voltage (140, 240) V, current Ip (12, 24, 50) A, pulse on time Ton (100, 200, 400) µs, and pulse off time Toff (3, 6.5, 12) µs were increased. An analysis of accuracy involved four adjustable parameters consisting of voltage (140, 240) V together with current Ip (12, 24, 50) A and pulse on time Ton (100, 200) µs. Higher values of voltage, current and pulse on time result in increased WLT according to test results.

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1. INTRODUCTION

1.1 Electro Discharge Machining

Electro discharge machining, spark erosion, spark machining, or electro-erosion is also referred to as spark machining. An electric spark must be continuously generated in an interrupted region of the metals to erode them, a process known as non-tom Eric machining, which is different from conventional methods that involve machining through a series of continuous intervals. Several thousand times/sec are repeated in the selected area of workpiece, and these repeatable steps are selected and repeated. This technique can be utilized to machine various metals and alloys, including very thin pieces, to precise dimensions and shapes (machining dies, for forging). Extrusion), any substance irrespective of its hardness. Furthermore, the EDM process is automated, reducing the reliance on the operators' skills.

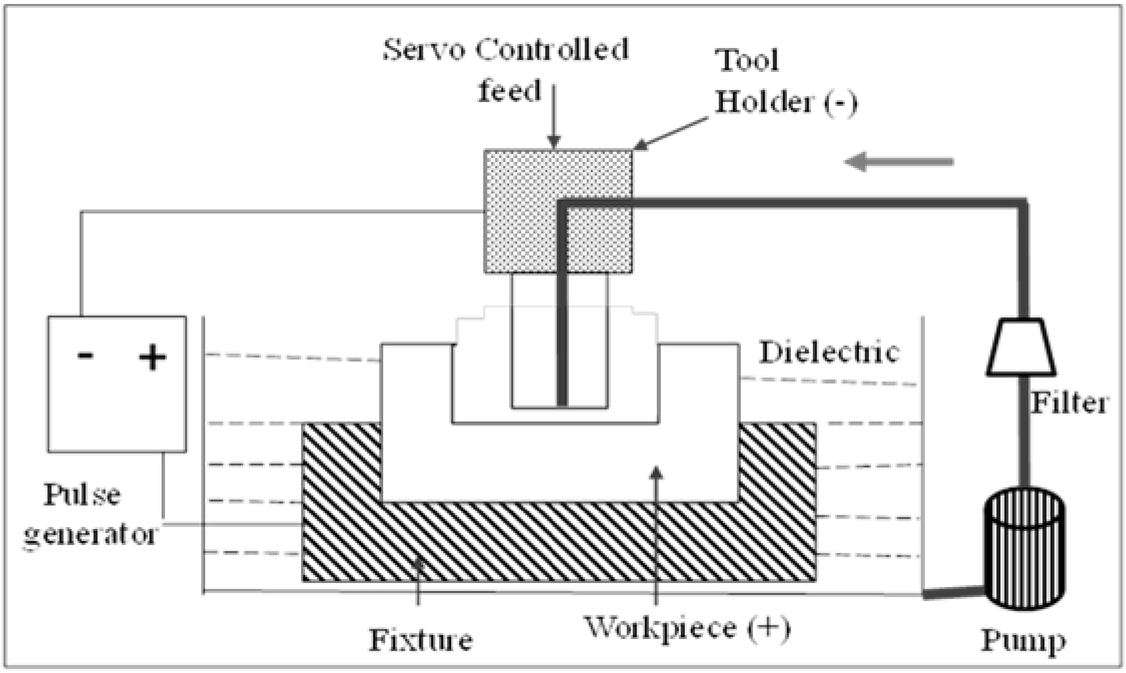

Figure. 1. Schismatic of Electro Discharge Machining.

Despite needing the workpiece to be electrically connective for EDM to machine, the tool's electrodes may wear out faster, resulting in the need for multiple electrodes to finish the process [1]. Such losses will surely be lessened by identifying a more effective and precise machining system that produces such losses.

1.2 The Principle working in EDM

EDM uses the heat energy of a spark to remove material from the work piece, which is a principle, used to remove the material. The tools and work piece are electrically connected to dc electric power despite having a small spark gap between them.(+) is connected to the positive terminal on the workpiece, where the positive terminal is used to connect. The anode is formed, and the cathode is employed (-). The space between(0.01 to 0.5) mm is available.

Insulator fluid filled the dielectric fluid on both the tool and work piece. Paraffin oil, transformer oil, and kerosene are the common dielectric fluids used. The gap between the tool and workpiece allows for the circulation of electric fluid through a pump with the aid of a nozzle. The production of thousands of sparks per second increases when the supply is turned 'ON'. Sparks have a very short duration of each spark, and they are very short in duration. When the spark encounters the dielectric fluid in the spark gap, it is then ionized with the fluid that reacts with the spark. Current flow is enabled to pass through it, thus ensuring the tools and workpiece are in good working condition [2] . The tool and work piece is housed in a reservoir and is electrically connected to a DC power source. The negative terminal is where the tool is wired to a negative terminal, which transforms it into a cathode, while the positive terminal is where the work piece is wired to a positive terminal, transforming it into an anode, Essentially, the tool electrode possesses the shape of the desired product, with some clearance along the side and some over cut along the edge, in terms of being shaped similarly to it. Figure. 1 shows a servo-controlled electrode as the sole electrode in the device that can be repeatedly sensed for a spark gap, and where the tool electrode is used to keep the spark gap closed because the too large gaps may prevent a spark from forming. Both the tool and the work piece will suffer damage from short circuits and short circuits, and short circuits can lead to deflection points.

1.3 White Layer Thickness in EDM

Milling of hard material with the EDM process results in superior high tolerance, surface finish, and cutting force ability compared to other methods, which typically involve milling. The EDM process utilizes thermal energy generated by the plasma column of electrical discharge to remove material by using the EDM process. A higher thermal output resulting from the ignition of the spark plasma is due to the need for melting and vaporizing the melted workpiece, which requires the creation of a white layer or recast layer with a thickness of m or less, due to the high thermal energy generated by the spark plasma [3].

White layer thickness (WLT) over the machined work part has a significant impact on the surface quality of the EDM processed specimen. Predicting the white layer thickness in EDM processes has been a common concern, but little research has been made on this topic. Research was conducted on the properties of white layer formation using Alternative Functional Fetal Incase Investigation (ANFIS) modelling, as determined by a Reference [4]. Of the four parameters that affect the total current the most the most are the peak current, pulse on time, pulse off time, and work-piece material.

White layers were only observed in cases where prior research emphasized the creation of such a layer at high cutting speeds, but the formation of such a white layer at such high cutting speeds has never been studied. Sharp edges and hardened materials experienced a decrease in severity with a lower tool wear rate, while white layer depth and hardness decreased as cutting speed increased [5] .The findings suggest that wear mode may be linked to the appearance of the white layer, rather than a clear or correlative relationship between the two processes. EDM involves utilizing the Taguchi technique to study the machinability of the (α–β) brass by means of its mechanical properties.

Experiments are conducted with three variables, which are the ones commonly used in machining: current, pulse-on time, and voltage. The customer has the option to choose from Material removal rates (MRR), Electrode wear rate (EWR), and Surface roughness (SR) as the output parameters for potential material handling, which are chosen by the customer. Peak current is a major determinant of all responses, as evidenced by the SN ratio analysis which makes them highly sensitive to the peak current, as peak current is a major determinant of all responses [6]. To determine the impact of various parameters, an analysis of variance (ANOVA) is utilized, which includes a statistical analysis of variance for each parameter to evaluate its contribution .

The formation of a white layer structure occurs while machining hardened steels because of the thermal-mechanical interaction that leads to deteriorating mechanical properties and decreased service capabilities in the machined part. The main cause of white layer formation despite lack of condensation is severe plastic deformation under cooling conditions whereas recrystallization and material phase changes do not occur [7]. Observed results show that the thickness of the white layer can be increased by augmented tool use, leading to results that show the white layer can be thinned out if the tool is not already in use, and that the thickness of the white layer can be improved if the tool is used to add thickness to the white layer, which is also an important benefit of tooling.

Surfaces are formed through melting, evaporation, re-solidification, and crater overlap in EDM techniques. According to almost all existing models of EDM, surface formation is classified as a thermal process within the EDM process, which remains excluded from the hydrodynamic processes discussed in reference [8]. The paper introduces a three-dimensional thermo-hydraulic coupling model through Lagrangian–Eulerian scheme based on solving this problem. A model was developed to simulate surface formation on a 2 A anodic workpiece through an accurate representation of both material property changes with temperature and temperature-dependent phase changes together with deformation patterns and practical forces.

Micro-hardnes, surface finish, white layer thickness, and environmental conditions are all improved through the use of an EDM process that employs graphite-argon gas as a dielectric medium. The EDM process now uses graphite powder as its dielectric medium because it is mixed with compressed argon gas. The analysis's target parameters consisted of gas pressure, discharge current, pulse width and gap voltage for reducing surface roughness as input variables. The main goal involved enhancing micro-hardness dimensions and white layer dimensions and minimizing energy utilization. Surface roughness reached its minimum value of 2.23 m when HN31 steel received input of gas pressure up to 1.0 MPa with maximum pressure at 1.0 MPa while using discharge current at 6 A for pulse width at 40s at gap voltage 40 V. The highest micro-hardness value reaches 501.04 HV when using 1.2 MPa gas pressure combined with 120 s pulse width while setting the gap voltage at 60 V and discharge current at 18 A [9]. The combined forces produce the maximum white layer thickness of 16.24 m which occurs through optimal pulse width of 160 seconds combined with white hole diameter of 140 mm and gap voltage set to 70 V and discharge current of 18 A.

During the EDM experiment a Taguchi L9 workpiece contains a stainless steel (D3) strip which uses Taguchi L9 design parameters. Response optimization conducted on independent factors MRR, TWR, SR will utilize Pulse-on-time (Ton), Current (A), and Voltage (V) for parameter optimization [10]. The gaming content includes only one brand. The values of optimal independent parameters along with their corresponding independent variables can be found by performing analysis of variance (ANOVA) and signal-to-noise (S/N ratio) evaluation. The combination of A-7 A and Ton-20 s and V-125 V and MRR constitute the most suitable parameters for predicting response variable optimization according to forecasts. The optimal parameters TWR and SR require A-1 A, Ton-10 s with V-100V and V-150 V respectively to achieve their assigned response variables.

Despite a relatively high local temperature increase, the heat is scattered due to a short time pulse on time and a lack of time for heat to dissipate. The area of heat affected (HAZ) within 2 - 4 m of the spark crater is located approximately 2 - 4 m away from the spark crater. Electrical discharge machining utilizes the electro-thermal process, which involves inserting the recast layer on a machined surface and the heat-affected zone (HAZ) directly below the machined surface. EDM process involves evaluating the white layer (recast layer), a crucial part of the process. The ability to predict white-layer thickness (WLT) of AISI A2 steel on electrical discharge machine-processed AISI A2 steel is the focus of research [11] and the development of a comprehensive mathematical model, based on a response-surface methodology, is made possible by the simulation of the mechanical properties of the treated AISI A2 steel. Furthermore, the WLT calculator is employed to consider the impact of the processing parameters on the process parameters and the minimum WLT by combining low-peak current and pulse-on time.

To assess surface integrity, a thorough experimental investigation is conducted including measuring residual stresses, changing surface composition, surface roughness and white layer thickness, heat affected zone analysis, surface morphologys, among other measures. Surface integrity studies are solely focused on the processing of specific steels, and nickel-based alloys, with specific research interests [12]. The choice of acquiring the alloy that would have produced the surface integrity study was not influenced by any other choice, as the alloy was a 2014 T6 alloy of aluminum and subsequently selected for its surface integrity study. residual stresses) ranging from 8.2 to 405.6 MPa, depending on the parameters defined by the parameters and the values obtained were varied across different values. The thickness of white layer and surface morphology is dependent on parameter settings, resulting in no cracks on the surface at all machining conditions during the process.

Advanced alloys exhibit a range of characteristics, such as wear resistance, corrosion resistance and high fatigue strength. CNC machines face numerous machining difficulties that are caused by conventional machining techniques. Among the various useful options, electrical discharge machining is a viable solution that can be used to address other problems [13]. Create a single discharge finite element model and simulate a three-dimensional axis symmetrical model using analysis software, while also converting it into a single discharge finite element model using a computer-generated simulation tool. The temperature profile is used to determine the rate of material removal, which is dependent on the temperature profile. Experimental results yielded an average error of 6.189 %, while numerical results yielded a mean error of 0.0050%, with their experimental results yielding 0.0428 % and their numerical results 0.0428 % respectively, Experimental and finite element model results provide an excellent correlation between these results and the experimental results.

The use of EDM enables machining hardened substances along with the manufacturing of hard material parts through the process of machining hardened substances. Titanium alloy properties distinguish them for high-precision modern uses which cover both titanium ores and different Titanium alloy applications. The exhibition performed a research study about EDM machining Titanium Grade2 while developing a simulation model. Machining performance indexes represented by Material Removal Rate along with Tool Wear Ratio and Average White Layer Thickness can be measured and calculated when using pulse-on currents and pulse-on times. The analysis included multiple cross-sectional heat exchange with deformed geometry simulation features which generated modeling capacity for estimating Plasma Flushing Efficiency and electrode-workpiece power transfer. The researchers produced regression models in Response Surface Methodology to associate machining parameters with outcomes which resulted in correlation models linking data to specific indices while performing ANOVA applicable to their mentioned indexes at high pulse-off times using Autodesic System [14]. The research adopts both experimental testing along with numerical modeling to advance a particular direction. The mechanical behavior and damage evaluation of near-surface layer mechanical parts was performed before EDM machining through experimental testing of these components. The production process manufactured qualified EDM parts by employing high-density electromagnetic (DM) gas [15]. In situ Mini-tensile tests with XRD help researchers study the mechanical fluorescence of near-surface layers exposed to EDM while undergoing residual strain effects and hardening thus enabling investigators to determine model-linked parameters. Plastic deformations occur more frequently at the base material to near-surface layer border where they generate increased damage along with micro-cracks due to fast-moving interface plastic deformations [16].

The quality of the precision machining of the parts needed to be accurate in relation to performance measures must be further improved, particularly when compared to other parameters, The average white layer thickness is often dependent on electrical process parameters, and in recent times, attempts have been made to incorporate the WLT instead of machined wings (refer to the present study), Examine the influence of WLT parameters and machining process parameters on the process analysis.

2. EXPERIMENTS SETUP

2.1. Material of the workpiece and electrode

The electrode material for analysis comprised pure copper (99.9% Cu) while the specific dimensions of this material were 82, 40 and 5 mm. The work part consisted of an AISI 444 stainless steel piece with dimensions of (40 x 30 x 2) mm. Table 1 contains all required chemical specifications of the workpiece material. The fixed EDM machine parameters appear in Table 2 followed by Machining parameters and their levels presented in Table 3.

Table 1. The chemical composition of the workpiece.

Element	Content %
Iron, Fe	77.475
Chromium, Cr	18.5
Molybdenum, Mo	2
Nickel, Ni	1
Manganese, Mn	1
Silicon, Si	1
Carbon, C	0.025

Table 2. Fixed parameters of the EDM machine.

Machining parameters	Fixed values
Workpiece polarity	Negative
Electrode polarity	Positive
Dielectric fluid	Transformer oil
S code	20
Gap code	9
Jumping Time	0.8 s
Servo feed	0.75
Working Time	0.6 s
Depth of cut	1 mm

Table 3.Machining parameters and it's levels.

Parameters	Units	Levels		
		Level 1	level 2	Level 3
Voltage	V	140	240	
Peak current (I_p)	A	12	24	50
Pulse on time (T_{on})	µs	100	200	400
Pulse off time (T_{off})	µs	3	6.5	12

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3. RESULTS AND DISSCUTION

Table 4 below summarizes the results of a study that encompasses all voltage values. To determine the most emotional input parameters to all output response in the cutting process,

Table 4. The experiment results of WLT.

No. of sample	Current I_p (A)	Pulse on T_{on} (µs)	Pulse off T_{off} (µs)	WLT (µm)	
				140 (V)	240 (V)
1	12	100	3	2.743	4.101
2	12	100	6.5	2.791	4.157
3	12	100	12	2.810	4.163
4	12	200	3	2.873	4.170
5	12	200	6.5	2.878	4.182
6	12	200	12	2.893	4.207
7	12	400	3	3.172	4.215
8	12	400	6.5	3.207	4.232
9	12	400	12	3.232	4.238
10	24	100	3	4.156	5.705
11	24	100	6.5	4.175	5.711
12	24	100	12	4.183	5.718
13	24	200	3	4.205	5.832
14	24	200	6.5	4.231	5.841
15	24	200	12	4.244	5.850
16	24	400	3	4.253	5.921
17	24	400	6.5	4.261	5.973
18	24	400	12	4.275	6.015
19	50	100	3	7.012	7.327
20	50	100	6.5	7.151	7.351
21	50	100	12	7.173	7.366
22	50	200	3	7.195	7.425
23	50	200	6.5	7.233	7.552
24	50	200	12	7.254	7.733
25	50	400	3	7.361	7.739
26	50	400	6.5	7.380	7.922
27	50	400	12	7.568	8.151

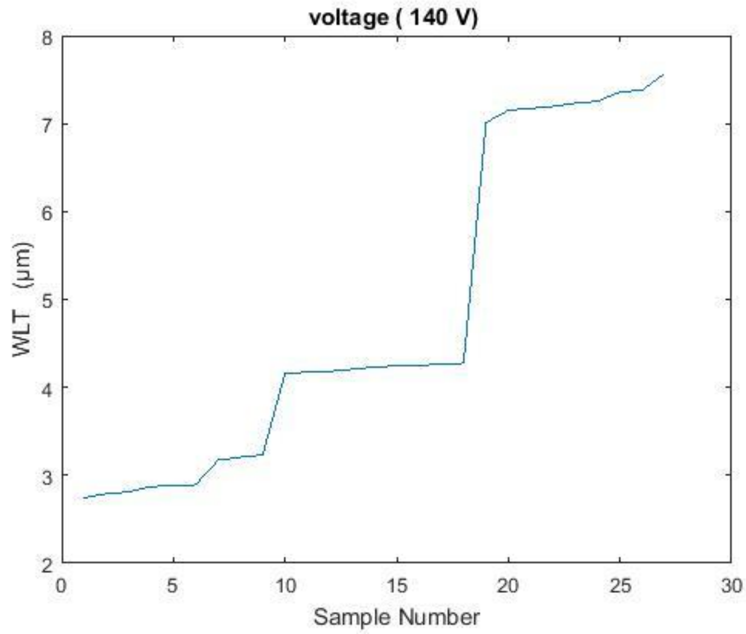

Figure 2: The figure depicts the connection between WLT and sample number when operating at 140V for 27 samples.

The data in Figure 2 shows how the WLT directly increases in proportion to the rising sample number when using 27 samples at 140V. The relationship between WLT and sample number appears the same in Figure 3 after raising the voltage to 240v according to Figure 3. The graph in Figure 4 shows that voltage values are compressed together proving that white layer thickness increases with experimental investigation.

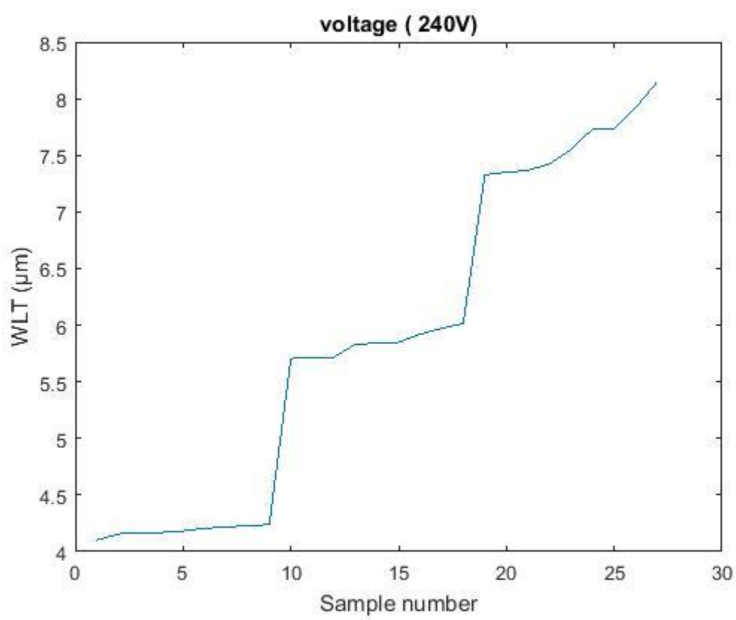

Figure 3.The WLT variable shows a relationship to sample number for 27 test samples while using an electric field strength of 240V.

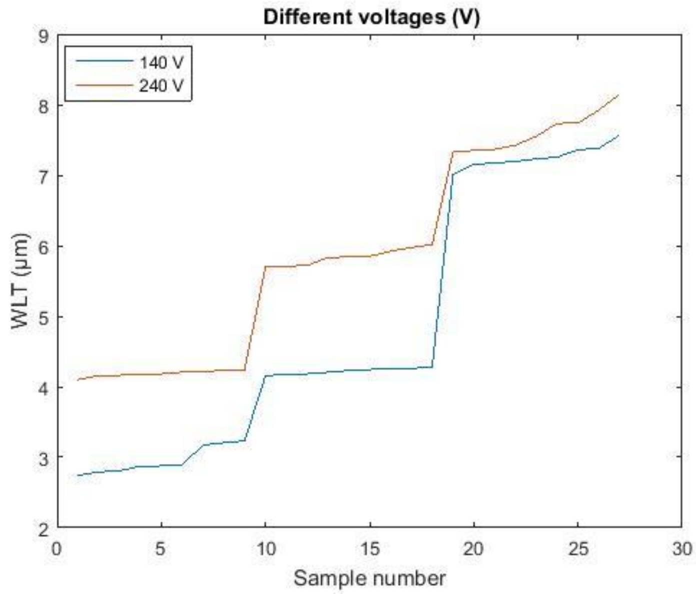

Figure 4: The WLT correlation appears samples tested at both voltages (140. 240V).

Figure. 1 shows how changing input parameters affects WLT because the measurement point below average represents the parameters' influence on the WLT value at that scale. WLT increases following voltage (V) and current (Ip) raises from (140 to 240 V) to (12 to 50) A while maintaining a direct correlation with the voltage (V) that elevates WLT because there is no observed change in current (Ip). The number of electrons generated with their resulting collisions produce powerful sparks that increase electrode and workpiece temperatures thereby causing meltage and vaporization and ultimately forming deep craters on the workpiece surface. A longer WLT develops when pulse on time (Ton) is increased between (100 to 400) µs and when Ton ranges between (100 to 400) µs so that WLT develops higher values. The plasma channel discharge lengthens the period needed for plasma channel discharge to convert into electrodes which results in decreased Toff time (SMT) from (3 to 12) µs because spark discharge time and intensity decrease. Due to size reduction of plasma channel units the workpiece has less effect on electrons. The procedure of disconnection, vibration loss of power source or improper misting or manipulation of the dielectric may result in incorrect placement. MRR reaches its peak value when Toff equals (6.5) µs under conditions of voltage (240) V and current (50) A and tonal time (400) µs.

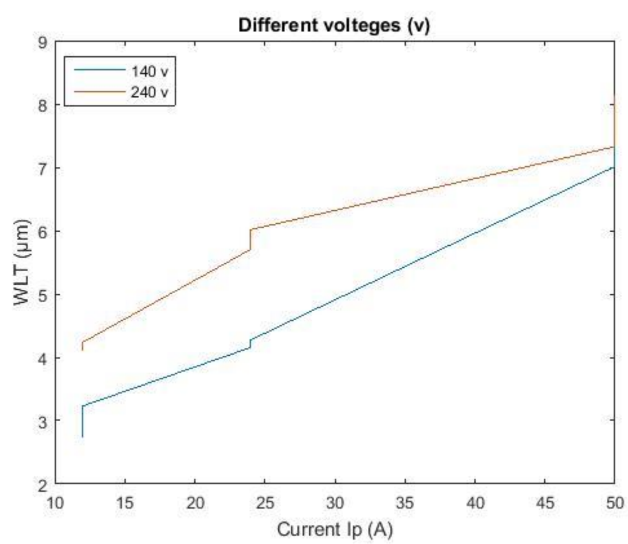

Figure 5:.The relationship between WLT and Current Ip(A) exists at two voltage levels of 140. 240V

Authors conducted an EDM study by controlling the parameters which included voltage set at 140 and 240 V and currents at 12, 24, 50 A and pulsing parameters of Ton set at 100, 200, 400 µs and Toff at 3, 6.5, 12 µs. The white layer thickness measurements indicate the influence of all parameters in this experiment (Figure 6). Attractive electro-caching required the use of cupper electrodes. Expert machining demands exact precision settings which become evident when the WLT benefits from 140 V voltage instead of using 240 V. The surface appearance of a component becomes unsatisfactory due to the voltage used for processing.

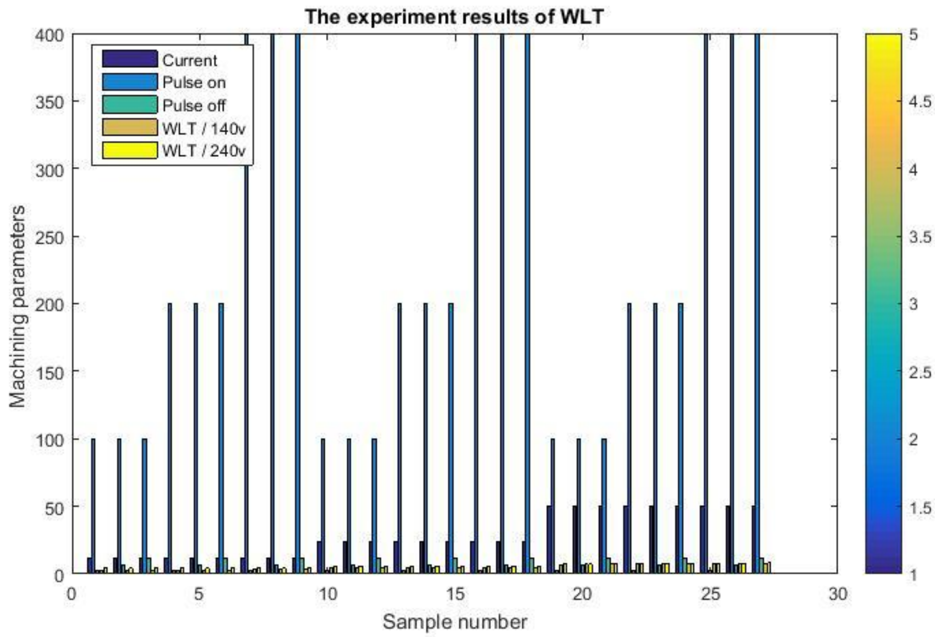

Figure 6. The Machining parameters and White layer thickness (WLT)

4. CONCLUSIONS

The paper explores EDM which stands as a common industrial unconventional machining system that produces detailed designs through extensive industrial utilization during many years. The ability of the work piece to respond correctly to environmental conditions stands as the only limitation when employing EDM. EDM research developed new areas focused on EDM domain because of substantial changes in both assisted processes and optimization techniques and process parameters. Every Feedback associated with non-electrical parameters has shown to depend heavily upon the confirmed non-electrical parameters thus resulting in diminished dependability in comparison to Electrical Discharge Machining. New EDM research opportunities emerged from modeling processes which enhanced EDM process effectiveness since their introduction during recent years. The proportional increase of WLT becomes greater as researchers vary voltage (V), current (Ip) or pulse on time (Ton). The strength of WLT deteriorates because the off-time pulse grows longer. The WLT reaches its maximum value of Toff (6.5) µs when using parameters of voltage (240) V, Ip (50) A, and Ton (400) µs. The minimum WLT parameters consist of Toff (12) µs and voltage (140) V, Ip (12) A and Ton (400) µs that serve as the base settings when restrictions such as Toff (12) µs do not apply.

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BIOGRAPHIES OF AUTHORS (10 PT)

Authors need to minimally consist of two individuals according to recommendation. One of them as a corresponding author.
The submission requires high-quality photos of 3x4 cm dimensions in addition to comprehensive vitae. Example of biographies of authors:

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