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Studying the effect of Depth of Cut on Electric Spark Machining parameters

Jabbar .k. Abbas [11], Shukry. H. Aghdeab[2]
[1 1]Department of Scholarships and Cultural Relations. Baghdad / MHESR. Iraq
[2]Nanotechnology and Advanced Materials Research Center (NAMRC), UOT, Iraq

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ABSTRACT

Several machining parameters impact the process's quality. These parameters may include variables such as the type of polarity, the kind of workpiece, the types of dielectric materials, methods for dielectric flow, and the selection of operational parameters, among other factors. This paper includes optimization studies designed to provide insights into the influence of these factors and the strategies utilized to achieve optimal performance. The study revealed that the depth of cut consistently increased with higher pulse time and current values. Additionally, the optimization of process parameters for the EDM process using a copper electrode was explored. Metal removal using electro discharge Machining (EDM) is primarily achieved through melting. The reported experimental results indicate an absence of melting, even during short pulses with a discharge duration of 5 seconds, despite their sensitivity to temperature variations. This is because short pulses do not provide sufficient time for the metal to heat up effectively (equivalent to approximately 45 minutes), leading to minimal or no melting. In the EDM parameters used, the depth of cut increased with higher voltage levels (140 V to 240 V), current (Ip) values (12 A, 24 A, 50 A), pulse-on time (Ton) durations (100 ms, 200 ms, 400 ms), and pulse-off time (Toff) intervals (3 ms, 6.5 ms, 12 ms). The increase in voltage (140 V to 240 V) and current (Ip: 12 A to 50 A) significantly contributed to the enhanced depth of cut. The ET system utilized for these parameters also showed a consistent increase in the depth of cut with rising voltage and current. Testing confirmed that these parameters positively influenced the depth of cut while simultaneously improving their combined effect. Four parameters-voltage (140 V, 240 V), current (Ip: 12 A), and pulse rates-were evaluated, revealing that as voltage and current increased, the depth of cut and overall performance improved, with gradual adjustments in pulse rates enhancing the process further.

Corresponding Author:

Jabbar k. Abbas
Department of Scholarships and Cultural Relations. Baghdad / MHESR.
Alnidal street, Baghdad, Iraq
Email: jabbarkadhim14@gmail.com

1. Introduction

EDM is a means of precision metal automation and, through arc erosion, it creates intricate, deep-dense, and complex-shaped openings in electro-conductive materials and is employed for shaping hard metals, This study focuses on examining the influence of EDM process parameters on the machining characteristics of tungsten carbide. The examination encompasses factors such as material removal rate, relative wear ratio, and surface finish quality of the machined workpiece. Among the options available, copper tungsten is the preferred choice for use as a tool electrode in EDM for cutting tungsten carbide. The cathode role of the electrode and the anode role of the workpiece lead to improved machining performance, resulting in superior outcomes for both the cathode and workpiece, This ensures that the negative polarity of the negative polarity allows negative polarity to maintain electrical balance while enabling a lower level of surface finish and a higher material removal rate, resulting in reduced tool wear and improved surface finish [1]. High open-circuit voltage is necessary for machining in Tungsten carbide due to its high melting point and hardness, making it highly machining-related. 50 kPa is the recommended flushing pressure for dielectrics. The combination of a high material removal rate, low relative wear ratio, and excellent surface finish achieved with a single set of control parameters cannot always lead to a simultaneous achievement of conflicting objectives, To achieve the best machining results, each stage of the machining process should have its own specific machining objectives that must be addressed separately during each stage.

Tungsten carbide rough EDM requires a much quicker removal rate than other methods due to its higher removal rate, which dramatically reduces the time required for machining [2]. Higher discharge currents enhance the material removal rate but also result in increased surface roughness on the workpiece. The surface roughness is directly proportional to the intensity of the discharge current, highlighting the trade-off between speed and surface quality in EDM processes.

To achieve superior surface quality and precision during machining, it is essential to establish optimal control settings, especially in the finishing phase. The parameters required to mill tungsten carbide include a gap voltage of 120 V, a discharge current of 24 A, a pulse duration of 12.8 s, a pulse interval of 100 s, a dielectric flushing pressure of 50 kPa, and tungsten carbide as the tool electrode material with negative polarity configured [3], Despite variations in machining conditions and external influences, research confirms that optimal conditions for machining tungsten carbide exist, albeit with minor adjustments influenced by material composition, machining accuracy, and external factors.

Die-sinker EDM, a versatile non-traditional machining method, employs an erosion-based approach for material removal. This process is particularly effective for shaping intricate, hard, and electrically conductive components in the presence of a dielectric fluid. Common applications include manufacturing forming tools used extensively in the automotive and aerospace sectors. However, as previously noted, the process does have limitations. For instance, the cost of fabricating electrodes in the EDM process constitutes over 50% of the total machining cost, which is a notable disadvantage. Selecting suitable electrode materials and optimizing machining parameters are therefore vital to justify the economic viability of EDM and to minimize production costs.

The electrochemical spark machining (ECSM) process combines features of electrical discharge machining (EDM) and electrochemical machining (ECM), utilizing electrolysis and electroplating effects based on Faraday's law. This study focuses on the advancement of ECSM, which evolved from a conventional drilling machine [4]. The research employed an L9 orthogonal array to optimize process parameters using a gravity feed system with the tool and electrolyte in a stationary setup.

An analysis of variance (ANOVA) for material removal rate (MRR) revealed that voltage plays the most significant role in material removal, followed by power cycle and electrolyte concentration. Through confirmation experiments, the optimal settings were identified. The MRR for ECSM, with parameters set to a voltage of 80 V, electrolyte concentration of 30%, and power cycle of 80%, was found to be 0.23366 mm^3/min [5].

In-situ electro-spark deposition (ESD) was utilized to create ultra-hard TiC, TiN, and Ti(C,N) layers on carbon steel substrates using a pure titanium electrode. The deposition process was carried out in various atmospheres, including argon, nitrogen, a mixture of argon and nitrogen, and air. The resulting coatings were analyzed using FE-SEM/EDS, X-ray diffraction, Raman spectroscopy, micro-hardness and nanoindentation tests, along with surface roughness measurements. Phase stability was evaluated through thermodynamic simulations based on approximations. It was identified that the primary phases-Fe_5C_2, TiN, Fe_3N, and Ti_2O_3—formed under argon, nitrogen, argon/nitrogen, and air atmospheres, respectively. These findings indicate the atmosphere-specific development of phases during the ESD process.

The surface hardening properties achieved through ESD were attributed to the presence of martensite at the coating-substrate interface in all atmospheric conditions. The asymmetrical nature of the ESD process was suggested as a potential cause for discrepancies between experimentally observed phases and those predicted by thermodynamic models. Gaseous environments [6], particularly argon and nitrogen, were shown to provide protective or reactive conditions for the titanium/steel system. The active nitrogen medium promotes an avalanche plasma regime during electro-sparking. Under argon flow, an FeTi intermetallic layer forms beneath the surface. Conversely, ESD in ambient air results in the development of Fe-Ti-O compounds and various TiO_n oxides.

The addition of nitrogen gas during ESD increased the coating's surface roughness and thickness compared to deposition in an argon atmosphere. This enhancement was attributed to the additional heat generated by chemical reactions, which contributed to increased coating thickness and roughness. The alternating flows of titanium, nitrogen, carbon, and oxygen led to the formation of Ti(C,N) at the surface, followed by the development of titanium oxides in the middle layers. The coexistence of Ti(C,N) as a super-hard material with a hardness of 3130 HV at the surface, along with titanium nitrides forming a gradient layer beneath it, effectively inhibited crack propagation, The chapter also covers how the fatigue life of 3D AISI D6 tool steel specimens, produced through three-dimensional cavity machining, is affected by the use of current settings (such as "laser calibrator") in combination with pulse-on time, thereby examining the impact of these settings on fatigue life. The fatigue performance of AISI D6 tool steel is greatly improved by the inclusion of these parameters, which also account for their influence on the steel's fatigue performance. By means of optical and scanning electron microscopy, microprobe analysis, and micro hardness testing, it is possible to analyze the surfaces of the fractured and masticated specimens in order to identify any leaks or damage, The outcomes indicate that the fatigue life of the specimens is adversely affected by electro discharge machining, which uses EDM techniques to machine them to a high degree.

The thickness of the material depends on the discharge energy from the exhaust current, which is highly variable, uniformity, and occurrence of solidification cracking within the recast layer, all of which also influence fatigue performance. Fatigue failure manifests in two distinct stages; however, the EDM process induces microcracks and tensile residual stresses within the damaged surface layer, which adversely shorten the fatigue failure stages into a single phase dominated by crack propagation. This process allows multiple fatigue cracks to initiate and extend into the underlying substrate, creating surface imperfections. Once these cracks reach a critical length, the fracture of the remaining cross-section occurs rapidly, provided sufficient material remains intact.

Despite the chemical composition of the recast layers being similar to that of the steel substrate, the recast layer exhibits significantly higher hardness values compared to the substrate material.

The high-cycle fatigue behavior of Inconel 718 alloy was investigated by analyzing the fatigue life of samples produced through electric discharge machining (EDM) and end milling, with an emphasis on samples processed at low discharge energy. The study aims to evaluate the impact of the recast layer formed during EDM on the fatigue performance of Inconel 718. Specimens were prepared in compliance with ASTM E606 standards to generate data under fully reversed fatigue conditions at ambient temperature.

Fabrication of the specimens was conducted using a die-sinking EDM machine that generates spark discharges. Fatigue tests were carried out to compare the fracture morphology and fatigue life between machined and fatigued specimens. The resulting fatigue behavior was evaluated by examining the effects of milling on the processed specimens and their fracture characteristics [6], The specimens were analyzed using optical and scanning electron microscopy, and surface roughness was measured with a standard profilometer. The results indicated that the fatigue life of samples produced by Spark Electric Discharge Machining (EDM) was marginally shorter compared to those manufactured through end milling, as reflected by a reduction in fatigue life. Data collection focused on key aspects such as the thickness of the recast layer, fracture mechanisms resulting from the EDM process, and observations from optical and scanning microscopy.

In recent years, the miniaturization of components has become increasingly significant in industries such as automotive, aerospace, and biomedical. This trend has driven innovative manufacturing solutions and substantial industrial efforts to support the development of smaller, high-precision components. EDM is widely employed in drilling applications across these industries, offering compatibility with diverse materials, including stainless steels, Alloys of titanium and a variety of other metals., In spite of their mechanical characteristics, any of these substances are not intended for use.

In the EDM process, material removal occurs as a result of electrical discharges between the electrode tool and the workpiece, which are created with a dielectric fluid, enabling material removal through a material removal process in the EDM process, Core components, such as dielectric fluid, electrode, and workpiece, are essential for electrical activation and material removal, The aim of this research is to investigate how the physical and thermal properties of dielectric fluids influence their effects on dielectric fluid properties., as well as the materials of the electrodes and workpieces, on the performance of micro-EDM drilling operations. Brass and tungsten carbide [7] electrodes were employed in experiments, which also tested experiments with three dielectric fluids, including two conventional types (water and mineral oil) and one unconventional type (vegetable oil). To gauge effectiveness, performance was evaluated using stainless steel and titanium alloy sheets as workpieces.

Key performance indicators, such as geometrical accuracy of holes, material removal rate (MRR), and tool wear ratio (TWR), were assessed and compared to standard benchmarks. The properties of the dielectric fluids, electrodes, and workpieces were directly linked to the observed outcomes, providing valuable insights for process optimization.

In a related study [8], the cutting performance in EDM, specifically cutting speed and surface roughness, was analyzed under varying cutting parameters, including pulse time, Dielectric flushing pressure, wire speed, open circuit voltage, and wire speed are all factors that must be considered, Mathematical regression models were employed to establish relationships between cutting performance outputs and the selected parameters. Additionally, a mathematical model was developed to optimize multi-output cutting processes in EDM. Statistical analysis and analysis of variance (ANOVA) were used to identify the most significant parameters affecting cutting performance.

The findings contribute to a deeper understanding of EDM processes and provide a foundation for further optimization efforts.

2. DEPTH OF CUT (DOC)

An electrical charge is discharged between the electrodes during the EDM process, An inward-compressing dielectric fluid between the electrodes is produced, resulting in the establishment of a spark channel through conduction, This channel consists entirely of plasma, a highly conductive state where atoms are ionized into positive ions and free electrons. Within the plasma region, electrical neutrality is largely maintained, as the density of positive ions is nearly equal to that of electrons.

Despite its neutrality, the plasma cannot sustain the voltage difference between the electrodes, typically around 102 V. Consequently, a thin plasma sheath forms near the negative electrode (cathode). This sheath contains an imbalance of charges, enabling it to support a potential gradient. The potential drop primarily occurs within this sheath, which can be observed near the electrode surface [Figure 1].

Within the plasma region, the potential is essentially uniform, classifying it as an equipotential zone. Minor variations exist between the plasma potential and the electrode potential, largely influenced by the positive electrode (anode). The cathode by way of contrast, it retains a negative potential in relation to the plasma potential. Defining zero potential as the plasma potential would allow for this type of study as the starting point for investigation.

The electric field close to the cathode is particularly strong because of the substantial potential drop within the thin sheath around the electrode, which creates a strong electric field due to the cathode's proximity, Negative charges become more and more apparent on the cathode surface when the field is switched [9], The field's action causes a lift of positive charges from the surface, leading to stress within the metal and raising tension on the surface, The discharge of heat from the discharge not only reduces the yield strength but also accelerates deformation by increasing the rate of stress deformation.

However, due to the brief duration of the discharge pulses, the metal does not have sufficient time to undergo significant heating. In such cases, shorter pulses do not substantially influence the temperature, resulting in negligible thermal effects. Conversely, for medium-duration pulses (lasting between 5 and 100 microseconds), the heating effect becomes more pronounced, The decay of the metal leading to a reduction in yield strength and an increase in the depth of the crater. Longer pulses, on the other hand, increase the spark radius and surface stress by a factor of two, leading to a significant increase in deformation on the surface but a decrease in spark intensity due to larger pulse durations and subsequent surface stress.

This indicates that while temperature plays a critical role in the EDM process, the contribution of electrostatic forces is relatively minor in comparison.

CNC machining parameters include the Depth of Cut, which is the measure of how much material is removed with a single cutting tool in a CNC machine. It is a vital part of machining operations, affecting everything from the quality of the final product to the functionality of the tool. There are two primary categories of depth of cut:

1- Radial Depth of Cut (RDOC), commonly referred to as stepover or cut width, is the unit of measurement of the degree of tangency or dexterity of the tool with respect to the material perpendicular to the tool’s axis. Milling and other operations require this to ensure the side coverage of the cutting tool is evenly distributed on the workpiece.

2- ADOC, which is also called step down or cut depth, measures the tool engagement along its axis and provides a vertical cut depth from the work surface.

To ensure efficient machining and maintain consistent positioning of the tool and workpiece, it is crucial to understand the depth of cut, as this directly affects tool accuracy and tolerance Nodes, Adjusting the depth of cut, you are essentially setting the bar for the amount of material the tool will remove from the workpiece in a single pass. The depth of cut is a vital aspect of the machining process, as it affects several crucial factors.[10]:

1- Productivity can be significantly enhanced by removing more material in less time when there is a greater depth of cut, which improves MRR at higher depths. Unless properly managed, this can cause significant energy demands and operational expenses, but also result in higher operating costs.

2- The force involved increases as the cut depth increases. Vibration, tool deflection, and tool failure may occur due to severe cutting forces, which can cause significant force surges and/or high cutting forces. The stability and accuracy of the machining process can only be maintained with controlled forces, which are essential for ensuring the machinery's stability and accuracy.

3- The thickness of the chips produced increases as cut depth increases. Thicker chips that are not easily controlled may affect the surface finish and make it more challenging to control. The cut's efficiency can be measured by examining the cutting parameters set, such as the depth of cut and indicating the chip type and manner of chip expulsion.

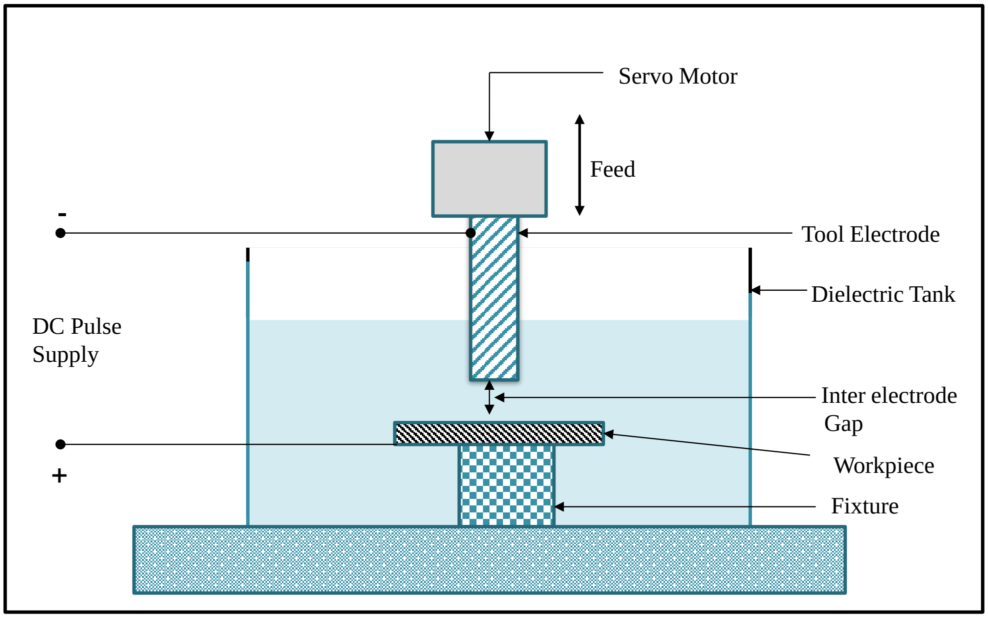

Figure 1. Schematic of an Electric Discharge Machining (EDM) machine tool

Electric Discharge Machining (EDM) is a thermo-electric, non-conventional machining process that is capable of simplifying the machining of hard conductive materials. It achieves this by removing both micro and macro-level particles that traditional machining methods [11] struggle to handle. Various parameters, such as voltage and current, are employed to control the machining process. AISI 444 stainless steel has a material removal rate (MRR) that is measured against the standard deviation for removing steel from various alloys, Using Minilab 19 software, we conducted a full factorial analysis based on the following EDM parameters: voltage (140, 240 V), current (12, 24, 50 A), pulse-on time (Ton) (100, 200, 400 µs), and pulse-off time (Toff) (3, 6.5, 12 µs). The results showed that the MRR increased with higher voltage. Specifically, at higher voltage, current, and pulse-on times, the MRR reached up to 144.2308 mm^3/min. This was achieved by using higher-than-average values for voltage and current, along with higher pulse-on times and lower pulse-off times [12].

The surface quality of miniature AISI 444 stainless steel was examined in the context of the Electrical Discharge Machining (EDM) process using a copper electrode with a diameter of 250 µm [13]. A total of 27 experimental runs were conducted, and the response surface methodology (RSM) was applied to analyze surface roughness parameters and identify the most significant factors. The study found that the depth of cut, approximately 40 micrometers, had the greatest influence on surface roughness, with spark duration (Ton) being the most significant parameter.

Our findings align with previous research in this field, and we confidently assert that our study offers improvements over prior work. This research can provide valuable insights for optimizing the EDM process when machining bars made of various hard materials. Table 1 presents the chemical composition, physical properties, and mechanical characteristics of the work material.

Table.1.Chemical Composition of AISI M2 work material

Element	Composition Range
Carbon (C)	≤ 0.025%
Manganese (Mn)	≤ 1.00%
Silicon (Si)	≤ 1.00%
Chromium (Cr)	17.5% – 19.5%
Nickel (Ni)	≤ 0.50%
Molybdenum (Mo)	1.75% – 2.50%
Nitrogen (N)	≤ 0.030%
Sulfur (S)	≤ 0.030%
Phosphorus (P)	≤ 0.040%
Titanium (Ti)	0.20% – 0.80%

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3. RESULT AND DISCUSSION

3.1. Experiments set

This study utilized an AISI 444 stainless steel workpiece with dimensions of 40 x 30 x 2 mm, while the electrode material was pure copper (99.9% Cu), with dimensions of 82 x 40 x 5 mm, The research objective was to use only pure copper electrode material. Table 2 defines the EDM machine's fixed parameters, which are found in Table 2. Analyzing parameters and its levels in Table 3. .

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	Changed

Table 3.Machining parameters and it's levels.

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

3.2. Experiments Analysis

Table 4 below presents the findings of a study that includes all voltage values. It helps identify which input parameters are associated with each output response in the cutting process and prioritize the most relevant ones for inclusion.

Table 4. The experiment results of Depth of Cut

No. of sample	Current I_p (A)	Pulse on T_{on} (µs)	Pulse off T_{off} (µs)	Depth of cut (mm) 140 (V)	Depth of cut (mm) 240 (V)
1	12	100	3	1.005	1.003
2	12	100	6.5	1.003	1.001
3	12	100	12	1.002	1.000
4	12	200	3	1.011	1.006
5	12	200	6.5	1.008	1.005
6	12	200	12	1.007	1.004
7	12	400	3	1.015	1.009
8	12	400	6.5	1.013	1.008
9	12	400	12	1.012	1.006
10	24	100	3	1.028	1.021
11	24	100	6.5	1.027	1.018
12	24	100	12	1.023	1.017
13	24	200	3	1.035	1.026
14	24	200	6.5	1.032	1.024
15	24	200	12	1.030	1.023
16	24	400	3	1.039	1.031
17	24	400	6.5	1.037	1.028
18	24	400	12	1.036	1.027

19	50	100	3	0.985	0.995
20	50	100	6.5	0.986	0.997
21	50	100	12	0.987	0.998
22	50	200	3	0.981	0.990
23	50	200	6.5	0.982	0.992
24	50	200	12	0.983	0.993
25	50	400	3	0.972	0.985
26	50	400	6.5	0.977	0.987
27	50	400	12	0.980	0.988

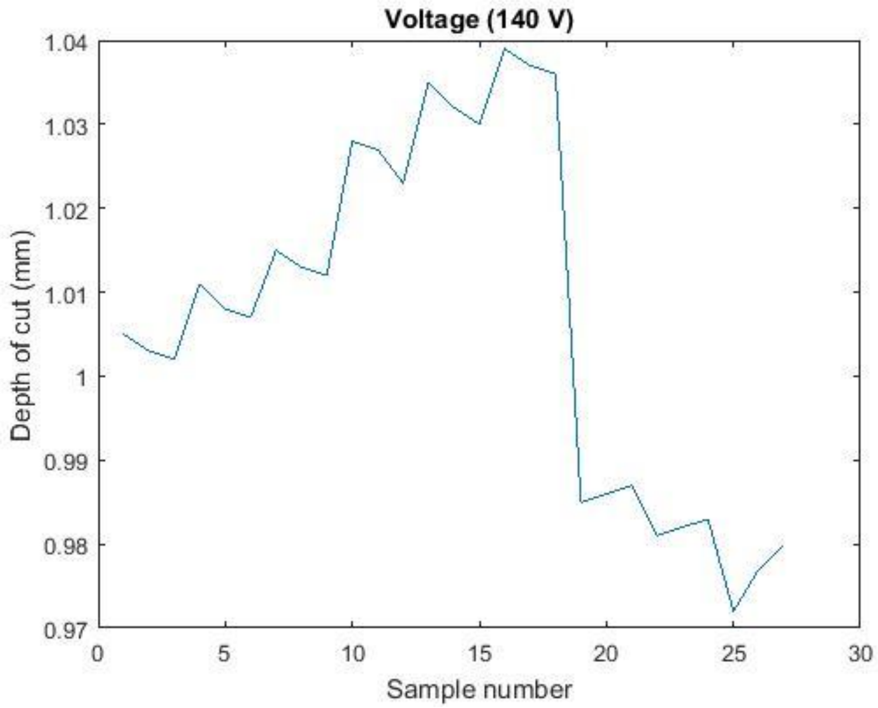
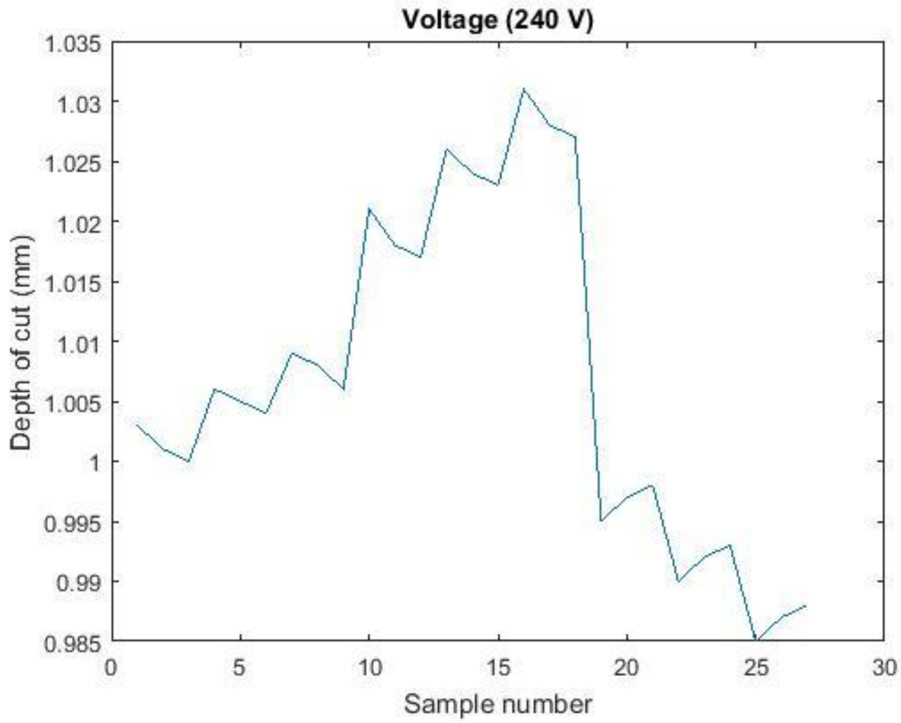
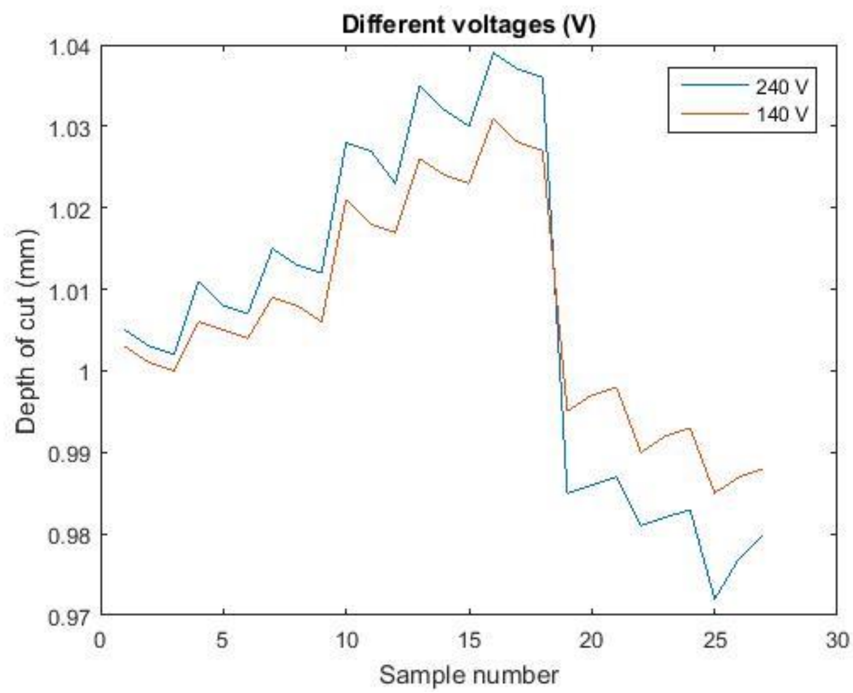


Figure 2: Relationship between the Depth of Cut and sample number for 27 samples and 140V

Figure 2 shows a direct proportional relationship between the depth of cut and the sample number, illustrating how the depth of cut increases with the sample number at a voltage of 140V for all 27 samples. Figure 3 displays a similar trend when the voltage is increased to 240V. Figure 4 highlights that, in both cases, the voltage values are closely packed, indicating an increase in the depth of cut, as evidenced by the experimental results.



Figore 3: Relationship between the Depth of Cut and sample number for 27 samples and 240V



Figore 4: Relationship between the Depth of Cut and sample number for both voltages (140. 240V).

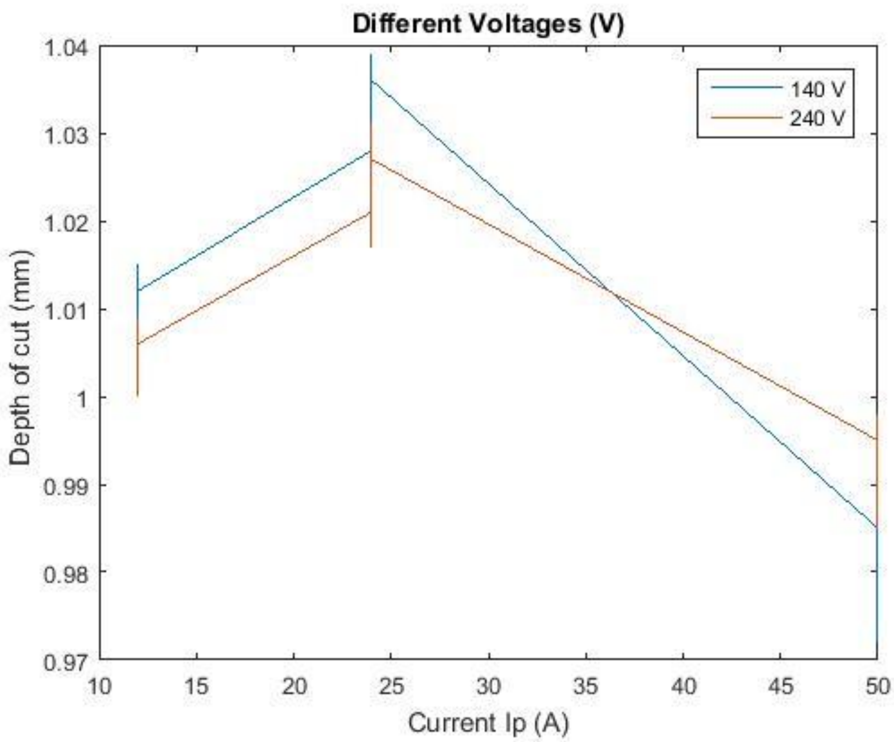
The depth of cut (represented on the depth of cut scale) demonstrates the influence of input parameters, with an average value of 1 below, on the impact of the depth of cut, as shown in Figure 4. A decrease in current (Ip) and an increase in voltage (V) from 140V to 240V and from 12A to 50A, respectively, results in a corresponding increase in the depth of cut. This is because the combination of increased voltage and current leads to stronger electron collisions, producing a more powerful spark that raises both the electrode and workpiece temperatures. This results in melting, vaporization, and the formation of larger craters on the workpiece surface.

Furthermore, increasing the pulse-on time (Ton) from 100µs to 400µs leads to an additional increase in the depth of cut, as a longer discharge time enhances the plasma channel's effectiveness. Conversely, a decrease in pulse-off time (Toff) from 3 µs to 12 µs reduces the spark discharge time and intensity, leading to smaller plasma channel units and minimizing the workpiece's influence on the electrons. Misplacement of the workpiece may occur if there is mist in the dielectric fluid, machine vibration, or power disconnection.

The highest material removal rate (MRR) is achieved at Toff = 6.5 µs, with maximum values for voltage (240V), current (50A), and pulse-on time (Ton = 400µs), which yields the highest MRR.

3.3. Depth of cut and Current (Ip)

This investigation included EDM parameters such as 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), The Depth of cut refers to these parameters as well as the parameters, one of which is current as depicted in Figure 5. These parameters are denoted by the Depth of cut. The correlation between Depth of cut and current is strictly related to voltage, as it will only result in a current of 25 A and a depth of less than 1.04mm and 1.03mm for voltages 140V and 240V, The relationship is altered to inverse direct because of the current value decreed. Electrocaching and cupper electrode usage are both essential, and cupper electrodes are utilized in tandem with cupper electrodes. High-quality machining often requires a certain level of machining precision, as evidenced by the fact that 14o V was better suited for machining at 240V. However, the voltage used in the machining can also cause the surface to appear low quality in terms of machinability in terms of machining precision.



Figore 5: Relationship between the Depth of Cut and current (Ip) for both voltages (140 V. 240V).

The relationship between the Depth of cut, Current Ip (from 12 (Ip) to 50 (Ip)), Depth of Cut (DOC), and machining parameters (Current (Ip), Pulse on Ton (µs) is established. Figure 6 displays the Toff (µs), which is the voltage difference between 140 V. 240 V. Figure 6 shows the voltage across the voltages, 140V. 240V. The behavior is influenced by the relation between fluctuation and increasing Pulse on (from 100 µs to 400 µs) and Pulse off (Toff (µs)) in each of the three charges ((3, 6.5, 12) µs)) as a function of which is predicted.

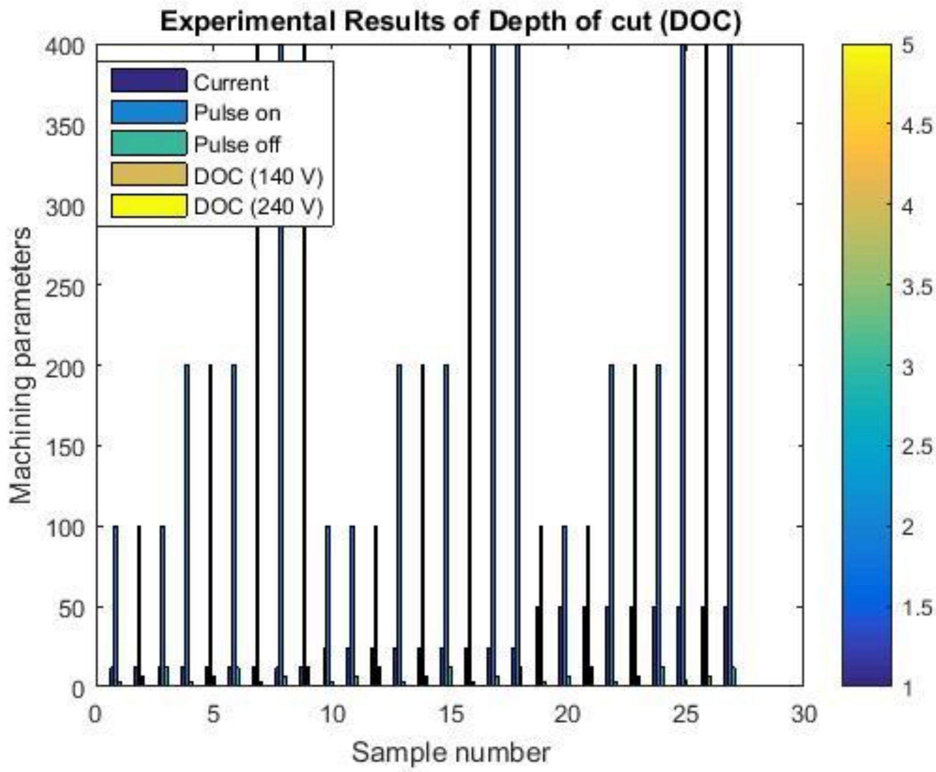


Figure 6. The Machining parameters and Depth of cut (mm**)**

4- CONCLUSION

EDM, a process that utilizes EDM technology in CNC machining, is frequently employed in industry, but it is a less versatile and intricate process that can produce intricate and detailed designs. The paper discusses its use in manufacturing. The only problem with EDM is that it demands work that can be formed that can adapt to the environment, which is a drawback of EDM methods. Since the mid-1980s, the EDM field has undergone significant changes in the assisted processes, optimization techniques, and process parameters it employs, leading to the development of novel research interests in the EDM domain, The dependence of the Feedback of non-electrical parameters on the verified Non-electrical parameters has been shown to be inversely proportional to the verification of the accuracy of the Non-electrical parameters, making the EDM process less dependable. The advent of modeling techniques and processes has greatly enhanced the efficacy of EDM processes, providing new research directions and new opportunities for research. The depth of cut increases proportionally with increases in voltage (V), current (Ip), and pulse-on time (Ton), but it decreases for sample number 19. This decrease is due to the increase in pulse-off time (Toff), which leads to a reduction in the depth of cut. The highest depth of cut is observed at Toff = 6.5 µs, with values of voltage (240 V), current (50 A), and pulse-on time (Ton = 400 µs). On the other hand, the lowest depth of cut occurs at Toff = 12 µs, voltage = 140 V, current = 12 A, and Ton = 400 µs, where Toff = 12 µs contributes to the minimum depth of cut without additional changes.

The relationship between the depth of cut and current is directly proportional up to a current value of 25 A for both voltages (140V and 240V). However, this relationship changes to an inverse proportionality once the current exceeds 25 A, as the depth of cut starts to decrease.

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BIOGRAPHIES OF AUTHORS (10 PT)

The recommended number of authors is at least 2. One of them as a corresponding author.
Please attach clear photo (3x4 cm) and vita. Example of biographies of authors:

Author 1 picture	**Dr. Jabbar k. Abbas**, Received His Msc. degree in the Fixturing sysytem engineering from University of Technology Baghdad – Iraq in 2001 and Doctor of philosophy in condition monitoring system from Nottingham Trent University –Nottingham, United Kingdome -2013. He has been a full-time researcher and in Nanotechnology and Advanced Materials Research Center at the University of Technology in ministry of science and technology, Baghdad, Iraq, Since December 2017, He also worked as ful-time researcher in the [1]Department of Scholarships and Cultural Relations. Baghdad / MHESR. Iraq ongoingHe can be contacted at email: jabbarkadhim14@gmail.com..
2 Author 2 picture	**Prof. Shukry. H. Aghdeab** Nanotechnology and Advanced Materials Research Center (NAMRC), University of Technology, Iraq Email: Shukry.H.Aghdeab@uotechnology.edu.iq