Engineering and Technology Journal
Journal homepage: engtechjournal.org

Investigation the Effect of Negative Polarity of Surface Roughness and Metal Removal Rate During EDM Process

Shahd A. Taqi [a]*, Saad K. Shather [b]

[a] Production engineering and metallurgy department, university of technology, Baghdad, Iraq.
shahad.adnan93@gmail.com

[b] Production engineering and metallurgy department, university of technology, Baghdad, Iraq.
dr.saadks@gmail.com

*Corresponding author.

Submitted: 06/02/2020 Accepted: 19/08/2020 Published: 25/12/2020

K E Y W O R D S

EDM, Revers Polarity, Electrode Metal, MRR, Surface roughness (Ra).

A B S T R A C T

The Electro discharge machine that named (EDM) is used to remove the metal from the workpiece by spark erosion. The work of this machining depends on the multiple variables. One of the most influential variants of this machine is the polarity, the material of the electrode, the current and the time pulses. Essentially the polarity of the tool (electrode) positive and the work piece is negative, this polarity can be reversed in this paper was reversed the polarity that was made the tool (electrode) negative and the work piece was positive. The aim of this paper was focused on the influence of reversed the polarity (negative) with changing the electrode metal (copper and graphite) on the surface roughness and metal removal rate by using different parameters (current and pulses of time). Experiments show that: the copper electrode gives (best surface roughness 0.46 µm when the current 5 Am and Ton 5.5 µs) and (worst surface roughness 1.66 µm when the current is 8 A and Ton 25 µs). And give (best values of the MRR 0.00291 g/min when the current is 8 and Ton 25 µs) and (The lowest values of MRR (0.00054 g/min when current is 5 and Ton 5.5 µs). The graphite electrode gives (best surface roughness 2.07 µm when the current 5 Am and Ton 5.5 µs) and (worst surface roughness 4.17 µm when the current is 8 A and Ton 25 µs). And give (best values of the MRR 0.05823 g/min when the current is 8 and Ton 25 µs) and (The lowest values of MRR (0.00394 g/min when current is 5 and Ton 5.5 µs).

How to cite this article: S. A. Taqi, and S. K. Shather, "Investigation the effect of negative polarity of surface roughness and metal removal rate during edm process," Engineering and Technology Journal, Vol. 38, Part A, No. 12, pp. 1852-1861, 2020.
DOI: https://doi.org/10.30684/etj.v38i12A.1591

1. INTRODUCTION

Electrical Discharge Machining was the nontraditional concept of machining. An EDM process is classified as modern machining process most commonly used in (the industrial field for making molds and dies. EDM mainly has been widely used for making dies, molds and punches. Also, it was used in the manufacture, processing to have a finished part for automotive, surgical components and aerospace industries.) The beginning of this machine goes far back to 1770, when English scientist Joseph Priestly was discovering the effect of erosion of electrical discharges on the metals, but this concept had not been taken till 1943 [1]. EDM machine is mainly made up of electrodes, which is the cutting tool and work piece, which both of them do not touch others [2]. The mechanism of removing the metals by generating a spark electrical between the poles as the (tool) electrode and the work piece, where the materials of both of the electrode and the work piece must be an electrically conductive for performed the operation [3].The behaviors of the material are different due to the differences made during the manufacture of each of the electrodes as well as for the piece of work in EDM and because each material has a different composition so it is necessary to know the properties of these materials to be customized on any electrode material that gives the highest materials removal rate and the best surface finish [4]. So in this paper was proposed to study the effected of various electrode materials and the input parameters are the currents and the pulses in the time on the output result are the materials removals rates (MRR) and the surface roughness (SR) [5]. Figure 1 shows the schematic diagram of the EDM system [6]. Ashikur Rahman Khan et al. studied the effected of the electrode metal such as (Cu and graphite) with negative polarity, they concluded that the peak current and pulse-on time are the most selected electrical parameters. As for the polarities, the copper electrode produces the best finish surface (less roughness), while the graphite electrode gives a high surface roughness [7]. Fred L. Amorim et al. investigated the substantial discharge current, discharge duration, electrode material and polarity. They concluded that can achieve higher metal removal rate MRR when used graphite electrode with negative polarity. Best surface roughness can result from the negative polarity for the copper electrode [8]. Praven et al. discussed the effect pulse time (ON/OFF) and electrode metal types when using reverse polarity conditions. The out-put result was the metals removal rate. The rate of metals removal (MRR) is increasing with the increases in pulse of the time Ton for both of two electrodes [9].

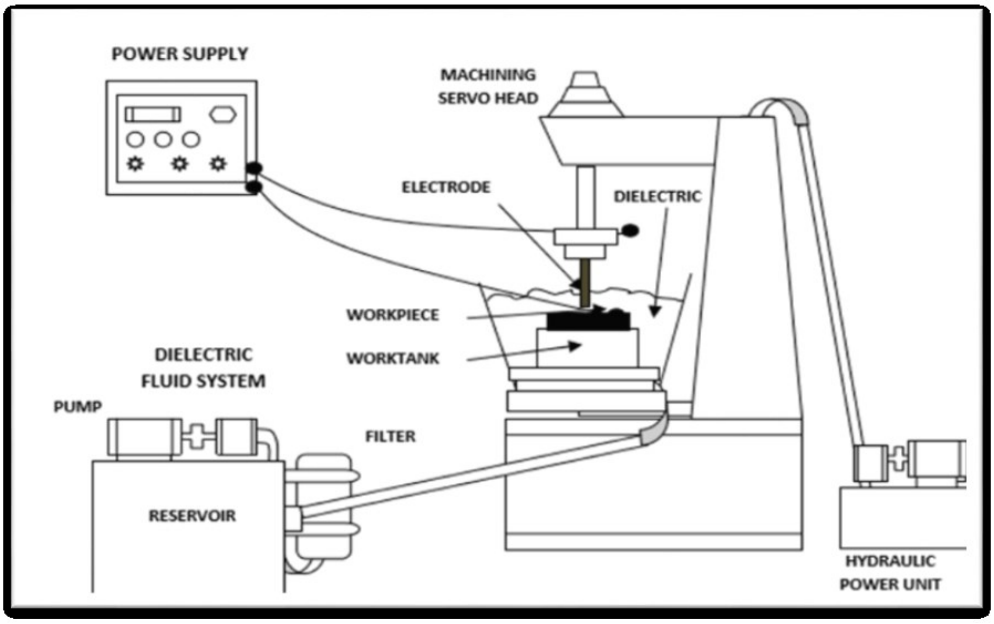


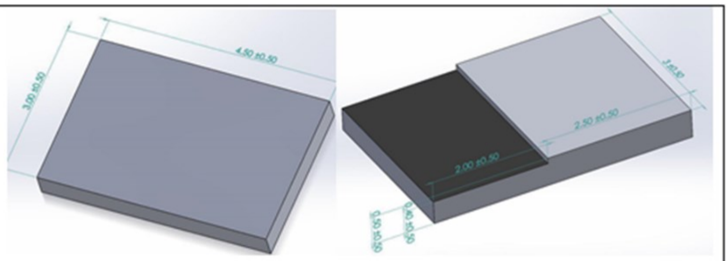
Figure 1: The schematic diagram of the EDM system [6].

2. EXPERIMENTAL WORK:

This paper showed the effect of change the electrode metal on the surface roughness and metal removal rate with used negative polarity. Parameters were used in these experiments (pules on time and current). The experimental work includes the following steps:

I. Work piece

The workpiece selected in this experimental work is low carbon steel. Low-carbon steel is the most common at this time because of its low cost and easy to form, as it provides physical properties that are acceptable in many applications and is a somewhat lightweight metal. The dimensions of workpieces (45 x 30) mm, these sizes have been selected for workpiece for easier to install in the machine, the form of the workpiece as shown in Figure 2, the chemical composition of the workpiece and The standard chemical composition of the low carbon steel are shown in Tables I and II respectively.



a) Workpiece before machining b) Workpiece after machining

Figure 2: work piece Low carbon steel.

TABLE I: The chemical composition of the work piece.

Element	**C%**	**Si%**	**Mn**	**P%**	**S%**	**Cr%**
Weight	0.0895	0.197	0.552	0.0081	0.0043	0.0164
Element	Mo%	Al%	Ni%	Cu%	Fe%	
Weight	<.002	0.0473	0.0282	0.0102	Bal	

TABLE II: The standard chemical composition of the low carbon steel [10].

Element	**C%**	**Si%**	**Mn**	**P%**	**S%**	**Cr%**
Weight	0.05-0.25	0.2	0.75	0.015	0.05	0.05

II. The tool metal (electrode)

One of the most important features or characteristics that must be provided in the electrode is physical conductivity, the resistance of corrosion, and fusion points that were given to the electrode (tool) a longer life. In this work that was used two types of electrode metals copper and graphite. The dimensions of the two electrodes are equal.

1) Copper electrode: the first electrode that is chosen is copper that it's shown with all dimensions in Figure 3, and the properties of the copper electrode were shown in Table III.
2) Graphite electrode: the second electrode that is chosen is graphite that is shown with all dimensions in Figure 4, and the properties of the graphite electrode were shown in Table IV.

TABLE III: properties of copper electrode [11].

Properties	**Values**
Phase	solid
Melting point	1084.62˚C

Boiling point	2562˚C
density	8.96 g⁄cm³
Modulus of elasticity (GPa)	16.5µm⁄(m.k) (at25˚C)
Thermal conductivity	401 W⁄(m.k)
Electrical resistivity	1.724×10^{-8} Ω.m
Electrical conductivity (S/m)	58.5
Modulus of elasticity (Gpa)	115
Thermal expansion coefficient (ppm/°C)	17.7
Hardness, HRB	62

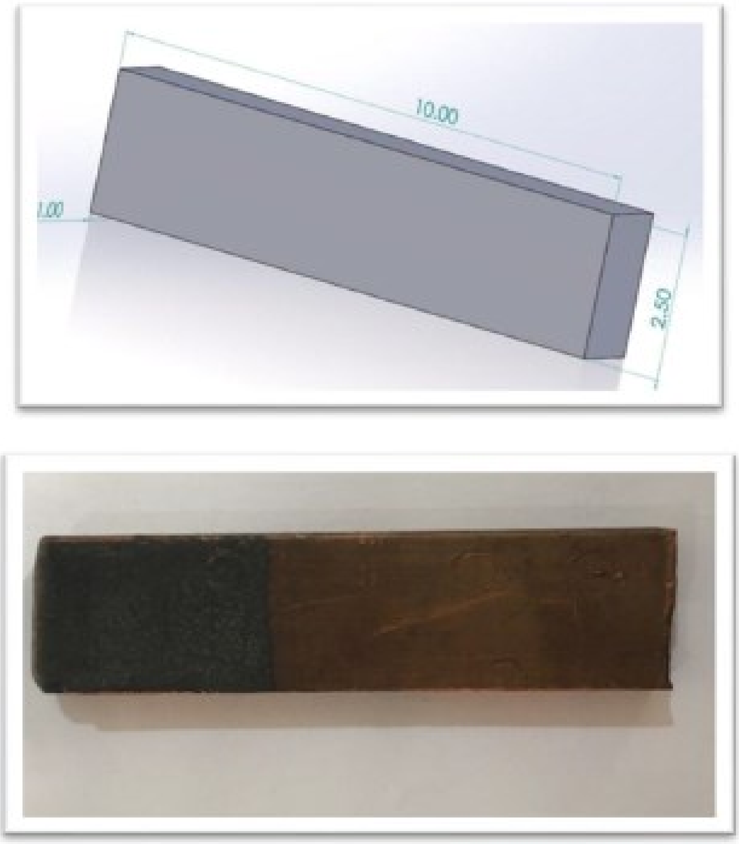


Figure 3: The copper electrode.

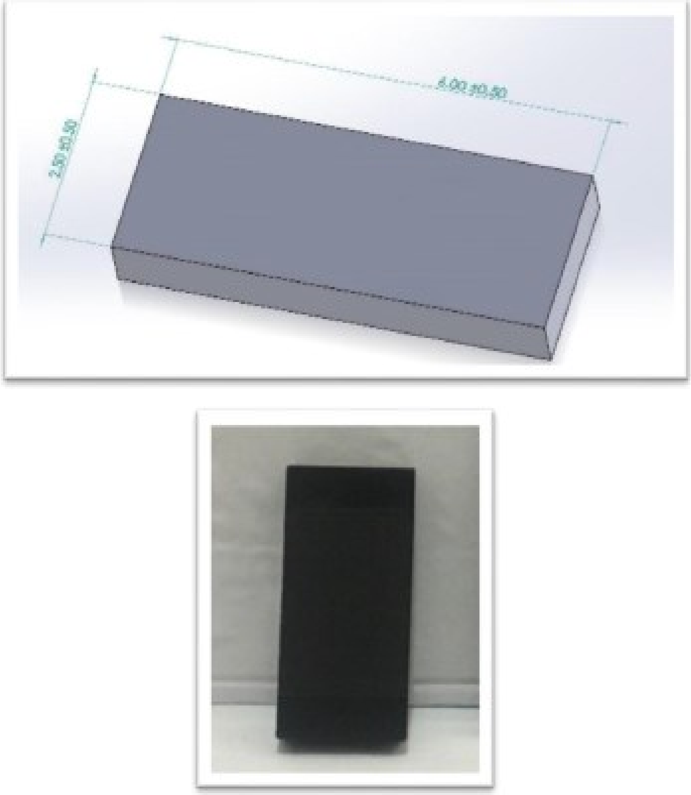


Figure 4: The graphite electrode.

TABLE IV:properties of the graphite electrode [12].

Properties	Values
Phase	solid
Melting point	2500˚C
Boiling point	3500˚C
density	1.3-1.95 g⁄cm³
Modulus of elasticity (GPa)	8-15 Gpa
Thermal expansion	1.2-8.2 µm⁄(m.k)
Thermal conductivity	25-470 w⁄(m.k)
Electrical resistivity	$(3\text{-}60)\times10^{-5}$ Ω.m

The graphite is stronger than copper and withstands the thermal and mechanical shocks and maintains its constant shape for a longer period while copper is characterized by the non-absorption of insulating liquid during operation and is less expensive, Sometimes both graphite and copper are mixed to get graphite copper to take advantage of all the distinctive qualities and benefits found in both copper and graphite. In these papers, each electrode material was used individually to determine the effect of changes when using each electrode material so the two metals were not merged and obtained an optimal material.

III. EDM machine

The ELECTRIC DISCHARGE MACHINE (EDM) is called CHMER for the model (CM 323C), shown in Figure 5. This device is designed to be used, operated, and controlled by the computer to ensure high accuracy, and the device contains many components.

Figure 5: EDM machine.

IV. Measurement of parameters

The variable parameters were performed to calculate the surface roughness (SR) and the metal removal rate (MRR).

V. Measurement of material removal rate (MRR)

The metal removal rate (MRR) is known that it's the rate of the difference in weight of the workpiece after and before the process of the machining time. (MRR) is calculated according to the following equation:

$$MRR = \frac{Wb - Wa}{t}$$

Where:
MRR: metals removal rate (mm3/min).
Wb: the work piece weight before the machining (g).
Wa: the workpiece weight after the machining (g).
T: the time of the machining (min).

VI. Measurement of surface roughness (SR)

Surface roughness measurement (SR) is performed in different areas on the automated surface. And take the average of these measurements as the last value of the roughness and measured by the "micrometer" grade. The profiling scale made by The Federal Maher, ps1 surf pocket type has been used to measure the roughness, the experimental constant parameters were shown in Table V.

TABLE V: Experimental constant parameters.

Constant parameters	Parameter values
Pulse off (Toff)	75 µs
High voltage	240 V
Gap voltage code	1mm
Servo feed rate (SVO)	75.0 %
Working time (WT)	1.4sec
Jumping time (JT)	1 mm
Dielectric fluid	transformer oil
Depth of cutting	0.25 mm

3. RESULTS AND DISCUSSION

Table 5 includes values for the experiments that were constant and Table 6 includes the results obtained as a result of using the negative polarity and changing the type of electrode metal with other parameters (current and Ton) and the effect of these parameters on both on the roughness (SR), metal removal rate (MRR). The metal removal rate was dependent on the energy of the generated spark (Es) is a function of the discharge current. The negative polarity means that the tool is the positive pole and the workpiece is the negative pole, the flow of electrons during this process from the workpiece to the tool. When using the negative polarity of both the copper pole and the graphite electrode, the results are significantly different from those obtained when using the positive electrode. Also, the outputs are not similar between the graphite electrode and the copper electrode. The results vary for metal removal rate and the surface roughness and will be discussing this output and the impact of parameters on it such as current and pules on time. The effect of increasing both of the current and pulse on time (Ton) on the metals removal rate of (copper and graphite) that occurs during the operation that shows in Figure 6 and figures 7. The reason for this an increase in the rate of metal removal when the increase both current and pulse on time, that the increase in discharge energy when the current increases and a longer time to convert this energy to the electrodes which in turn leads to generating of high spark energy that it's necessary to remove the particles from the workpiece. The relationship between both (the current and the pulse on time) with the surface roughness (SR) show in Figures 8 and 10 Where the effect of both the current and pulse time Ton on the roughest, that when increases both the current and pulse time Ton, leads to an increase in the surface roughness. The reason is that when the current increases the discharge energy increases and this leads to an increased metal removal rate and generates larger craters, thus increasing the roughness of the surface. The reason is that when the current and pulse time Ton increases, the discharge energy increases and this leads to increased metal removal rate and generates larger craters, thus increasing the roughness of the surface, results of the experimental work was shown in Table VI.

TABLE VI:Results of the experimental work

No. Expt.	Electrode	Current Am	Ton µs	TM (min)	MMR g/min	Rs µm
1	Copper	5	5.5	299	0.00054	0.46
2	Copper	5	12	82	0.00088	0.78
3	Copper	5	25	48:12	0.00097	1.04
4	Copper	6	5.5	36:33	0.00116	0.74
5	Copper	6	12	65	0.00131	0.98
6	Copper	6	25	55:33	0.00203	1.27
7	Copper	8	5.5	122	0.00145	0.88
8	Copper	8	12	140	0.002261	1.08
9	Copper	8	25	33:40	0.00291	1.66
10	Graphite	5	5.5	39:07	0.00706	2.07
11	Graphite	5	12	9:33	0.01413	2.29
12	Graphite	5	25	8:03	0.03001	3.14
13	Graphite	6	5.5	36:38	0.0106	2.27
14	Graphite	6	12	8:58	0.0184	2.58
15	Graphite	6	25	3:05	0.04533	3.73
16	Graphite	8	5.5	15:39	0.0126	2.69
17	Graphite	8	12	1:33	0.0392	3.02
18	Graphite	8	25	4:01	0.05823	4.17

Figures 6 and 7 show the relationship between the change in current and pules on time with MRR, it has been observed that there's an increase in the value of the metal removal rate (MRR) for both electrodes (graphite and Cu) when increasing current and pulse on time values. The reason of this increase in the rate of metal removal when the increase of both of them is owing to the increase in the energy of discharge when the current increases, as well as a longer time to convert such energy to electrodes, and this, in turn, causes the generating of elevated energy of spark that it is necessary to remove the particles from work piece. The graphite electrode is higher in the values of the metal removal rate (MRR) than the copper electrode. The reason for this is that the graphite electrode has a higher electrical conductivity and melting point than copper, this has led to higher discharge energy and therefore generated higher sparks faster and intense, this makes the graphite electrode has higher metal removal rates than copper.

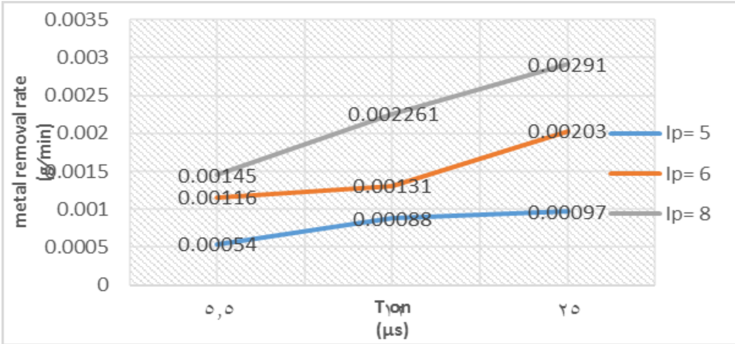


Figure 6: The effect of current and pules of time on MRR for a negative copper electrode

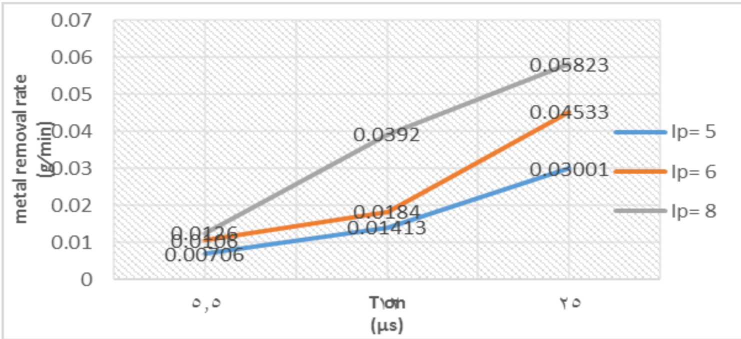


Figure 7: The effect of current and pules of time on MRR for negative graphite electrode

The RS of all electrodes increases with the raised current as well as a pulse on time, as shown in Figures 8 and 9, but the graphite electrode has the worst (greatest) surface roughness, differs from the copper electrode where it has the best (less) surface roughness. The reason for this is the high electrical conductivity of the graphite electrode, which makes the spark generated to have high energy when it collides with the workpiece and forms deeper craters and thus increases the roughness of the surface and forms a rough surface when using the graphite electrode.

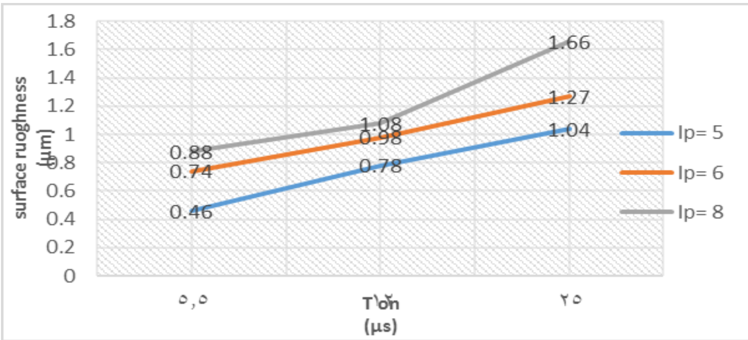


Figure 8: The effect of current and pules of time on SR for a negative copper electrode

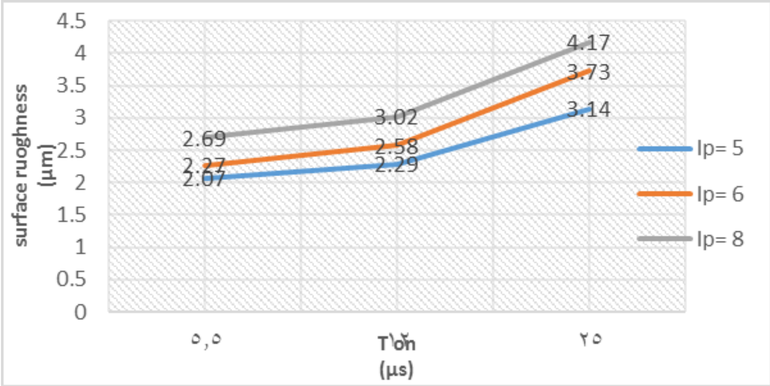


Figure 9: The effect of current and pules of time on SR for negative graphite electrode

4. Conclusions

From experiments can be concluded that:

1) The metal removal rate (MRR) and the surface roughness (SR) are increasing as the increase of the current and pulse-on time for both types of metals.
2) The copper electrode gives the low value of surface roughness (SR) (the best) and the lowest metal removal rate (MRR). The best values (SR 0.46 µm when the current 5 Am and Ton 5.5 µs and MRR 0.00291 g/min when the current is 8 and Ton 25 µs). The worst values (SR 1.66 µm when the current is 8 A and Ton 25 µs and of MRR 0.00054 g/min when current is 5 and Ton 5.5 µs).
3) The graphite electrode gives the higher value of MRR (the best) and higher SR. The best values (SR 2.07 µm when the current 5 Am and Ton 5.5 µs and MRR 0.05823 g/min when the current is 8 and Ton 25 µs). The worst values (SR 4.17 µm when the current is 8 A and Ton 25 µs and of MRR 0.00394 g/min when current is 5 and Ton 5.5 µs).
4) The copper electrode takes more machining time than the graphite electrode.
5) Regardless of the type of metal used, the highest value is obtained for the rate of metal removal and surface roughness when using the highest value of the current.

References

[1] A. Begum, and D. R. Reddy, "Effect of polarity on the machining characteristics and surface generation in EDM," Materials Today: Proceedings 4, no. 8, 7674-7679, 2017.

[2] B. P. Gavali, C. A.Waghmare and S. S. Kalashetty, "Experimental investigation of changing polarity in powder mixed electric discharge machining (PM-EDM)," International Journal of Engineering and Technology, vol. 8, no. 5, pp. 2049–2058, 2019.

[3] S. K. Shather, "Improving the metal removal rate (MRR) in electro discharge machining by additives powder," Engineering and Technology Journal 34, no. 14 Part (A) Engineering, 2766-2774, 2016.

[4] A. Begum, and R. Reddy, "Effect of polarity on the machining characteristics and surface generation in EDM," Materials Science and Engineering, Vol. 4, no. 8, Pages 7674-7679, 2017.

[5] S. A. Taqi, S. K. Shather, "Influence of polarity of electro discharge machine (EDM) on surface roughness (sr) and metal removal rate (mrr) of low carbon stee," Engineering and Technology Journal, Vol. 38, Part A, No. 07, Pages 975-983, 2020.

[6] L. Praveen, P. G. Krishna, L. Venugopal, and N. E. C. Prasad, "Effects of pulse ON and OFF time and electrode types on the material removal rate and tool wear rate of the Ti-6Al-4V Alloy using EDM machining with reverse polarity, " In IOP Conference Series: Materials Science and Engineering, vol. 330, no. 1, p. 012083. IOP Publishing, 2018.

[7] P.B. Gavali, C. A.Waghmare and S. S. Kalashetty "Experimental investigation of changing polarity in powder mixed electric discharge machining (PM-EDM)," International Journal of Engineering and Technology (IJET), vol. 8, no. 5, 2016.

[8] Md. A. R. Khan, and M.M. Rahman, “Surface characteristics of Ti-5Al-2. 5Sn in electrical discharge machining using negative polarity of electrode,” International Jornal Of Advanced Manufacturing Technology, vol. 92, pp. 1-13, 2017.

[9] I. Santos, M.I. Poli, and D. Hioki “influence of input parameters on the electrical discharge machining of titanium alloy (TI-6AL-4V),” International Journal of Manufacturing Research, 10(3):286, 2015,2015.

[10] M. Galai, M. Rbaa, Y. E. Kacimi, M. Ouakki, N. Dkhirech, R. Touir, B. Lakhrissi and M. E. Touhami, “Anti-corrosion properties of some triphenylimidazole substituted compounds in corrosion inhibition of carbon steel in 1.0 M Hydrochloric Acid Solution,” Analytical and Bioanalytical Electrochemistry, vol. 9, no. 1, pp. 80-101, 2017.

[11] L Praveen, P Geeta Krishna, L Venugopal and N. E. C. Prasad, “Effects of pulse ON and OFF time and electrode types on the material removal rate and tool wear rate of the Ti-6Al-4V Alloy using EDM machining with reverse polarity, ” IOP Conf. Series: Materials Science and Engineering, vol. 330, 2018.

[12] H. B. Özerkan, “Effect of changing polarity of graphite tool/ Hadfield steel work piece couple on machining performances in die sinking EDM, ” MATEC Web of Conferences ICMTMTE, vol. 129, 2017.