Shukry H. Aghdeab
Production Eng.& Metallurgy Dept., Univ. of Technology, Baghdad, Iraq
Shukry_hammed@yahoo.com

Nagham G. Ghazy
Production Eng.& Metallurgy Dept., Univ. of Technology, Baghdad, Iraq
naghamgh.ghazey@yahoo.com

Received on: 20/06/2017
Accepted on: 20/12/2017

Effect of Current and Duty Factor for Different Electrode Shapes on Material Removal Rate in EDM

***Abstract**-This paper discusses the performance of Electrical Discharge Machining (EDM) process by changing the bottom shape of the electrode, including two stages: designing the electrodes by turning process then the resulted electrodes were used to machine the workpiece by EDM. The effect of electrode shape on material removal rate (MRR) has been investigated for material of CK 60 carbon steel for workpiece and material of brass for electrode. The shapes of the electrode bottom were flat, conical (with 90° apex angle) and round (with 8 mm radius) of constant diameter electrode of 16 mm. Experiments were repeated for three current values of (10, 20 and 42 A) and three duty factor values of (0.4, 0.8, and 1). The results of experiments showed the main effect of current and duty factor on MRR. From experimental work, it is found that for most of experiments flat electrode gives highest MRR as compared to the two other shapes. A mathematical model was developed by factorial design to predict the values of MRR for different electrode shapes, currents, and duty factors by the Minitab Statistical Software (MSS).*

***Keywords**- CK 60 carbon steel, Electrical discharge machining, Electrode shape, Factorial design, Material removal rate.*

How to cite this article: Sh.H. Aghdeab and N.G. Ghazy, "Effect of Current and Duty Factor for Different Electrode Shapes on Material Removal Rate in EDM," *Engineering and Technology Journal*, Vol. 36, Part A, No. 6, pp. 633-640, 2018.

1. Introduction

Electrical Discharge Machining (EDM) is process in which the workpiece is shaped through the action of high frequency discrete electrical discharges (sparks) produced by pulse generator, where the workpiece and electrode are immersed in a dielectric fluid. Tiny amount of the workpiece material erodes by every spark that melts and vaporizes it, and so on until the cavity finishes to become the complementary shape of electrode geometry over the workpiece [1]. It is an advanced machining process, which is, used to machine difficult to machine materials with the traditional machining process and high strength temperature resistant alloys [2]. It uses thermal energy to machine electrically conductive workpieces in regardless of their hardness [3]. The thermal energy, which is transformed from electrical energy, ionizes the dielectric fluid and machines the material from the electrode and workpiece [4]. The machinability of workpiece material depends on its thermal and electrical properties and electrode properties in EDM. For example, copper as electrode has a low electrical resistivity, causing more heat transfer to the workpiece and more MRR. The cost of a produced part is determined mainly by the electrode cost that contains the raw material cost, production cost and number of electrode required for operation [5]. With EDM, it is possible to machine pre hardened steel with intricate contours or cavities without the need to soften it through heat treatment, and then re-harden it later [6]. EDM is used in a large number of industrial areas: automotive industry, electronics, domestic appliances, machines, packaging, telecommunications, watches, toys, aeronautic and surgical instruments [3].

(*Symbols, Greek, & abbreviations*):
I_p: Current (A)
M_T: Machining time (min)
N: Number of experiments
R-Sq: Determination coefficient
R-Sq (adj): Adjusted determination coefficient
R-Sq (pred): Predicted determination coefficient
W_A: Workpiece weight after machining) g)
W_B: Workpiece weight before machining (g)
ρ_w: Workpiece material density (g/mm^3)
τ: Duty factor
AdjMS :Adjusted mean squares
Adj SS: Adjusted sums of squares
ANOVA: Analysis of variance
CNC: Computer numerical control
DF: Degree of freedom
DOE: Design of experiments
EDM: Electrical discharge machining
E.S: Electrode shape
MRR: Material removal rate (mm^3/min)
MSS: Minitab Statistical Software

https://doi.org/10.30684/etj.36.6A.6
2412-0758/University of Technology-Iraq, Baghdad, Iraq

2. Principle of EDM

In EDM erosion effect removes, the workpiece material by thermal source causes generation of rapidly sparks between the electrode and workpiece [2]. The electrode is shaped electrode that makes cavities or holes in the workpiece. One of poles of power source is connected to electrode and another is connected to workpiece [7]. The electrode is separated from the workpiece by a small gap that is controlled by a servo system to give electrical resistance in gap [2, 7]. There will be generation of an electric field between the electrode and the workpiece when an electrical pulse delivers. When voltage is increased at the beginning of the pulse,it increases the temperature of a conductive bridge across the gap which ionizes the gap and forms spark between the electrode and workpiece surfaces [7]. The positive ions and electrons are accelerated because of heat that gives a conductive plasma channel [2]. Voltage is reduced and current is increased at the mid- point of the pulse, leading to increase in temperature and pressure of the plasma channel that melts and vaporizes small amount of material from electrode and workpiece surfaces at the discharge point producing vapor bubble that expands outwardly from the plasma channel [7]. When the pulse is stopped, the temperature is reduced, spark is terminated, and the plasma channel and the vapor bubble are collapsed. Explosive expulsion occurs for molten material from electrode and workpiece surfaces when the dielectric fluid is injected forming small crater in both surfaces. In only microseconds this entire sequence takes place. Because the presence of the contact separated between the electrode and the workpiece no force is generated during machining. Figure 1 shows the main parts of EDM [7]. In this paper, an experimental investigation is carried out to identify the influence of each machining parameter (electrode shape, current, and duty factor) on the MRR to know which electrode shape gives highest MRR. A mathematical model was developed by factorial design to create plot that explains the influence of electrode shapes and predict the values of MRR for these variables by the Minitab Statistical Software (MSS).

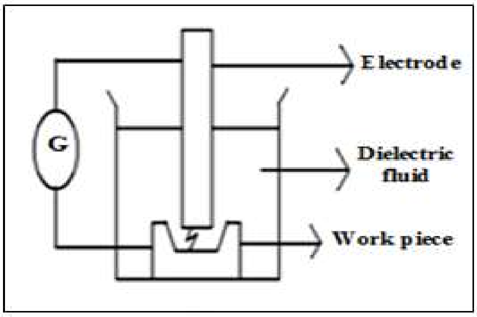

Figure 1: Main parts of EDM [7].

3. 0Planning of Experiments

I. Details of workpiece and electrode assembly

Every workpiece with 55 mm diameter and 2 mm thickness was cut from a round bar by process of wire electrical discharge machining (WEDM) of material of CK 60 carbon steel, as shown in Figure 2.The material is susceptible to magnetization and wieldable, difficult to manufacture, has (poor machinability and corrosion resistance, thermal conductivity of 43 W/m.K, electrical conductivity of 6×10^6 S/m, melting point of 1400 °C maximum, density of 7.9 g/cm^3 at 25°C, and hardness of 335 HB or HRB). In the laboratories of the Central Organization for Standardization and Quality Control in Al-Jaderiya, Baghdad, the chemical composition of the elements that form CK 60 carbon steel alloy was obtained in their weight percentage (Wt %), as shown in Table 1. An electrode with 16 mm diameter and 100 mm length is utilized. Three bottom shapes of electrodes were designed by turning process using CNC lathe USK-310 machine using flat, conical (with 90º apex angle) and round (with 8 mm radius) shapes, as shown in Figure 3. Extra high leaded brass was electrode material, it is easy to fabricate and machine, has (low cost and wear resistance, thermal conductivity of 115 W/m.K, electrical conductivity of 2×10^7 S/m, melting point of 885 °C for solidus, density of 8.5 g/cm^3 at 20º C, and hardness of 40-89 HB or HRB).

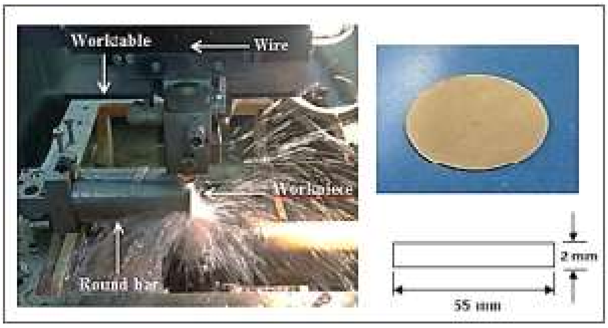

Figure 2: Cutting a round bar into workpieces by WEDM process.

Table 1: The chemical composition in weight percentage (Wt%) of CK 60 carbon steel workpiece.

Element	C	Si	Mn	P	S	Cr	Mo	Ni
Wt %	0.165	0.245	0.441	0.015	0.005	0.907	0.018	0.031
Element	Al	Co	Cu	Nb	Ti	V	W	Pb
Wt %	0.003	0.007	0.029	0.002	0.001	0.165	<0.005	<0.001
Element	Sn	B	Ca	Se	Sb	Ta	Fe	
Wt %	0.008	0.001	<0.0005	0.004	<0.005	0.03	remainder	

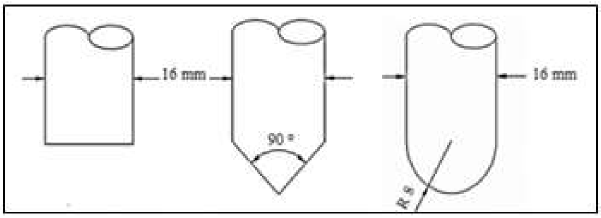

Figure 3: Sketch of bottom shapes of electrodes.

II. Selection of process parameters

CHMER EDM machine of CM 323C model is used to perform the experiments with die Sinking EDM process in Training and Workshops Center / Turning Unit in the University of Technology by producing a round hole in the center of workpiece with machining depth of 6 mm or more. Table 2 shows the three variable parameters in the process includes (electrode shape, current, and duty factor), and Table 3 shows the constant parameters.

Table 2: Variable parameters of the process.

Variable parameters	Level 1	Level 2	Level 3
Electrode shape (E.S)	flat	conical	round
Current (I_p)	10 A	20 A	42 A
Duty factor (τ)	0.4	0.8	1

Table 3: Constant parameters of the process.

Constant Parameters	Description
Workpiece material	CK 60 carbon steel
Workpiece thickness	2 mm
Electrode material	Extra high leaded brass
Dielectric fluid	Transformer oil

To calculate the values of MRR for each experiment, the weight of the workpiece before and after machining must be measured by the sensitive balance Instrument and the machining time must be recorded from machine screen when machining was finished by using the following equation:

$$\mathrm{MRR} = \frac{W_B - W_A}{M_T \times \rho_w} \quad (1)$$

Where:

MRR= Material removal rate (mm^3/min).

W_B= Workpiece weight before machining (g).

W_A= Workpiece weight after machining (g).

M_T = Machining time (min).

ρ_w=Workpiece material density (g/mm^3).

4. Design of Experiments (DOE)

DOE was done to check the influence of factors or predictors on response or performance at the same time for a set of experiments, in which changes are made to factors. It also improves process quality by identifying the process conditions, and optimizes the results by determining the factor settings using Minitab Statistical Software (MSS). Factorial design was used from the four designs of MSS.

Knowing the relative importance of the factors on response is the way to enhance the process by full factorial design. In this design, achieving the best way to run the process is by trying various combinations of factors settings [8]. Easy interface is provided to specify model terms and to calculate predicted values, and automatic model selection is provided to know important factors. General full factorial design is the selected type, which has 2 to 15 factors, each factor, can have a level differs from another factor (including 2 to 100 levels). The three selected factors were electrode shape with three text levels of (flat, conical, and round), current with three numeric levels of (10, 20, and 42), and duty factor with three numeric levels of (0.4, 0.8, and 1.0) and one for number of replicates which means that 27experiments is produced from the equation of 3^3 ($\text{level}^{\text{factor}}$), as shown in Table 4.

Table 4: Design of experiments.

No.	E.S	I (A)	D.F	No.	E.S	I (A)	D.F	No.	E.S	I (A)	D.F
1	flat	10	0.4	10	conical	10	0.4	19	round	10	0.4
2	flat	10	0.8	11	conical	10	0.8	20	round	10	0.8
3	flat	10	1.0	12	conical	10	1.0	21	round	10	1.0
4	flat	20	0.4	13	conical	20	0.4	22	round	20	0.4
5	flat	20	0.8	14	conical	20	0.8	23	round	20	0.8
6	flat	20	1.0	15	conical	20	1.0	24	round	20	1.0
7	flat	42	0.4	16	conical	42	0.4	25	round	42	0.4
8	flat	42	0.8	17	conical	42	0.8	26	round	42	0.8
9	flat	42	1.0	18	conical	42	1.0	27	round	42	1.0

5. Results and Discussion

I. Flat Electro

The influence of current is shown in Figure (4) with the use of currents of (10, 20, 42 A) on MRR for different duty factors using values of (0.4, 0.8, 1.0). It is clear that with increase of current, the MRR increases for all duty factors. The increasing of MRR is because of high energy at discharge point that produces strong spark giving higher temperature, which increases both the diameter and depth of crater in workpiece surface [5]. The influence of duty factor is shown in Figure 5with the use of duty factors of (0.4, 0.8, 1) on MRR for different currents using values of (10, 20, 42 A). It is clear that with increase of duty factor, the MRR increases but after a certain value of duty factor of 0.8, it increases slightly for current of 10 A. At high duty factor, pulse on time increases causing more discharge energy of the plasma channel that increases amount of heat transfer which becomes enough to melt and vaporize workpiece surface producing rise in MRR[9]. Slight increase of MRR is due to some reasons like dielectric liquid pollution, and difference of taper in holes [10]. Also, it is clear that with increase of duty factor, the MRR increases but after a certain value of duty factor of 0.8, it reduces for current of 20 A. Higher duty factor of 1with higher pulse on time makes plasma channel to expand that reduces energy density on the discharge point which are not enough to melt and vaporize workpiece surface producing reduction in MRR [11]. In addition, it is clear that with increase of duty factor, the MRR increases for current of 42 A. At high duty factor enough heat is generated to melt and vaporize workpiece surface producing rise in MRR, as it discussed in current of 10 A.

II. Conical Electrode

The influence of current is shown in Figure 6with the use of currents of (10, 20, 42 A) on MRR for different duty factors using values of (0.4, 0.8, 1.0). It is clear that with increase of current, the MRR increases for all duty factors. The reason of increasing MRR is increasing discharge energy with current, which makes higher number of electrons collide with the surface of workpiece causing increasing for material of workpiece [12].

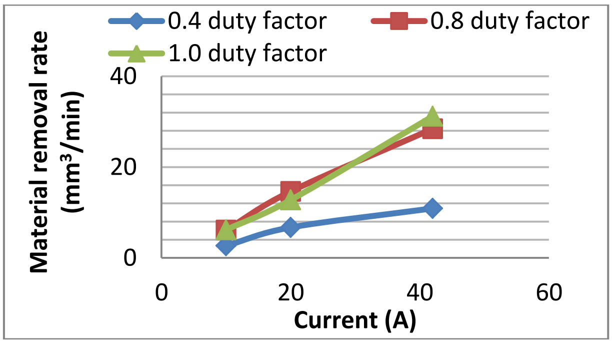

Figure 4: Influence of current on MRR for different duty factors using flat electrode

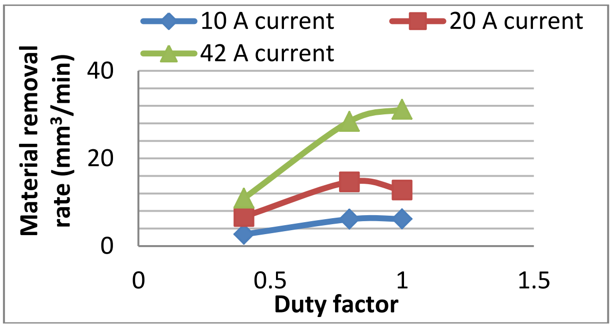

Figure 5: Influence of duty factor on MRR for different currents using flat electrode

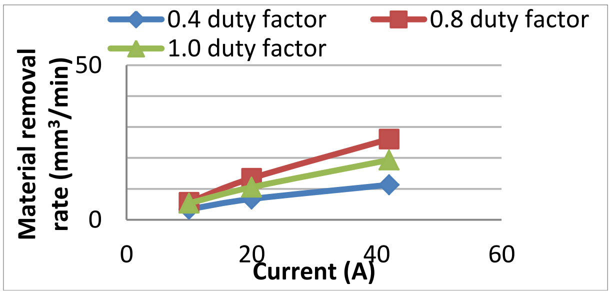

Figure 6: Influence of current on MRR for different currents using conical electrode

The influence of duty factoris shown in Figure 7with the use of duty factors of (0.4, 0.8, 1.0) on MRR for different currents using values of (10, 20, 42 A). It is clear that with increase of duty factor, the MRR increases but after a certain value of duty factor of 0.8, it reduces slightly for current of 10 A. High duty factor means higher spark energy that increases the workpiece removal-producing rise in MRR [13]. Slight reduce of MRR is due to some reasons like difference of taper in holes, vibration in dielectric liquid, and electricity shutdown [10]. In addition, it is clear that with increase of duty factor, the MRR increases but after a certain value of duty factor of 0.8, it reduces for currents of 20 and 42 A. Higher duty factor of 1 gives less flushing time of debris from workpiece surface that causes short circuit condition producing reduction in MRR [14].

III. Round Electrode

The influence of current is shown in Figure 8with the use of currents of (10, 20, 42 A) on MRR for different duty factors using values of (0.4, 0.8, 1.0). It is clear that with increase of current, the MRR increases for all duty factors. The increasing of MRR is due to incresed current densities produce large amounts of heat, which rapidly heats the workpiece and causes its remove [5].

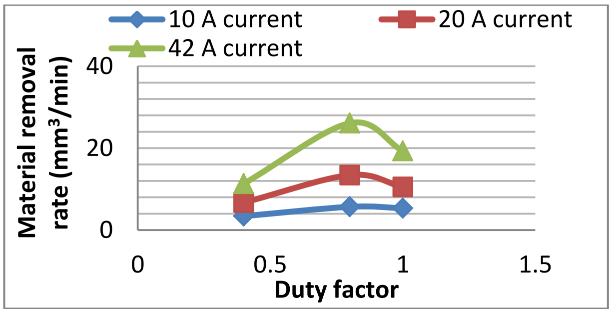

Figure 7: Influence of duty factor on MRR for different currents using conical electrode.

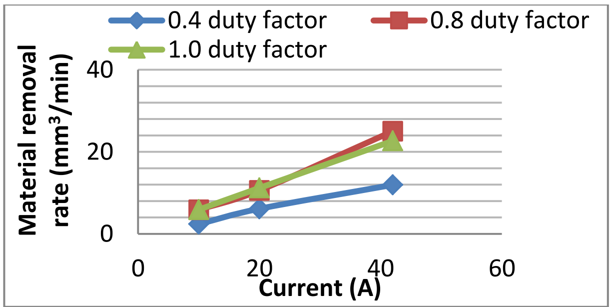

Figure 8: Influence of current on MRR for different duty factors using round electrode.

The influence of duty factor is shown in Figure 9with the use of duty factors of (0.4, 0.8, 1.0) on MRR for different currents using values of (10, 20, 42 A). It is clear that with increase of duty factor, the MRR increases but after a certain value of duty factor of 0.8, it increases slightly for currents of 10 and 20 A. High duty factor leads to applying the discharge for longer duration producing rise in MRR [5]. Slight increase of MRR is due to some reasons like dielectric liquid vibration, dielectric liquid pollution, and difference of taper in holes [10]. Also, it is clear that with increase of duty factor, the MRR increases but after a certain value of duty factor of 0.8, it reduces for current of 42 A. Higher duty factor of 1 with higher pulse on time increases the diameter of workpiece crater that leads to increased machining time producing reduction in MRR [15].

IV. Influence of Electrodes Shape

The experimented values of MRR are shown in Figure 10including nine experiments for each electrode shape (flat, conical, and round). For most of experiments, it is clear that flat electrode gives highest MRR as compared to conical and round electrodes. This increase occurs because of higher active area between the flat electrode and workpiece including all surface area to be the sparking area which increases thermal energy density on surface of workpiece in the gap, while active areas is less focused in a point and a region in conical and round electrodes, respectively gives lower energy density at first and as electrode advances towards the workpiece, energy density progressively increases at each instant which leads to strong heat on workpiece surface causing more melting and vaporizing, so conical and round electrodes give less MRR values [16].

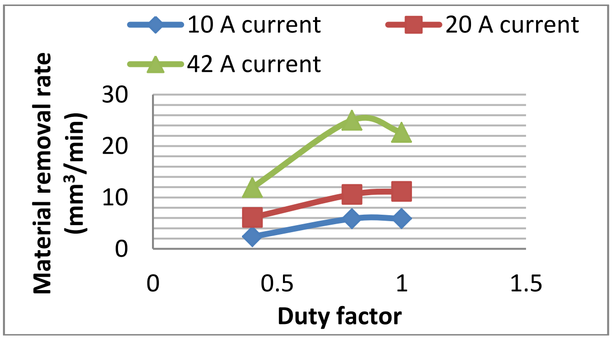

Figure 9: Influence of duty factor on MRR for different currents using round electrode.

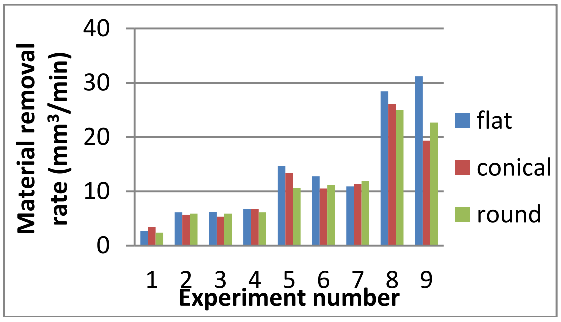

Figure 10: Influence of electrodes shape on MRR.

V. Prediction in Minitab Statistical Software (MSS)

Confidence interval of 95% analyzes the experimented values in the general full factorial design by MSS with general linear model. For the data there was a model to fit them to create residual plots to know the importance of the effects such as normal probability plot between the residuals versus their expected values when the distribution is normal using regression and ANOVA. The normal probability plot of residuals for MRR is shown in Figure 11. Figure 11 shows a clear pattern (the points are almost in a straight line) indicating that all the factors and their interaction affect the MRR. In addition, the errors are normally distributed and the regression model is well fitted with the observed values.

The output from an analysis of variance (ANOVA) arranged in a table includes the sources of variation, the degrees of freedom (DF), the total sum of squares (Adj SS), the mean squares (Adj MS), the F-values and P-values to determine whether the predictors or factors are significantly related to the response, as shown in Table 5 which indicates that current and duty factor affect significantly with P-value of 0.000 with significantly interaction effect of (current × duty factor) with P-value of 0.003. Percentage contribution of each factor on MRR is measured from analysis of variance (ANOVA) table. It is clear that current has largest percentage contribution to the total sum of squares of (67.98 %), duty factor of (20.3 %), and electrode shape of (1.36 %), as shown in Table 6.

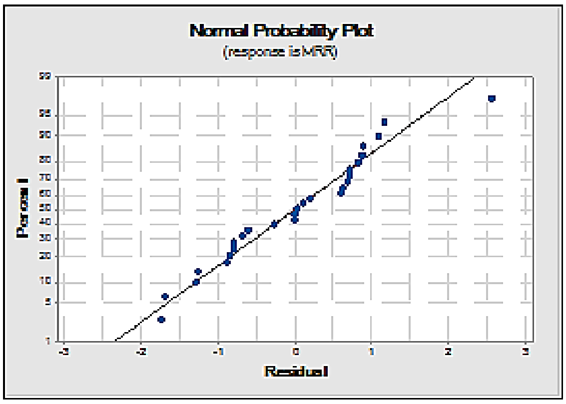

Figure 11: The normal probability plot of residuals for MRR.

Table 5: Analysis of variance (ANOVA) table for MRR.

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	18	1734.72	96.373	29.11	0.000
Linear	6	1554.96	259.160	78.27	0.000
Electrode shape	2	23.64	11.819	3.57	0.078
Current	2	1179.24	589.619	178.08	0.000
Duty factor	2	352.08	176.042	53.17	0.000
2-Way Interactions	12	179.76	14.980	4.52	0.020
Electrode shape × Current	4	18.10	4.524	1.37	0.327
Electrode shape × Duty factor	4	25.57	6.393	1.93	0.199
Current × Duty factor	4	136.09	34.023	10.28	0.003
Error	8	26.49	3.311	-	-
Total	26	1761.21	-	-	-

Table 6: Percentage contribution of each factor on MRR.

Factor	DF	Adj SS	Contribution (%)
Electrode shape	2	23.64	1.3628
Current	2	1179.24	67.9787
Duty factor	2	352.08	20.2961
Electrode shape × Current	4	18.1	1.0434
Electrode shape × Duty factor	4	25.57	1.4740
Current × Duty factor	4	136.09	7.8451
Sum=		1734.72	

Model Summary displays the statistics that compare how well different models fit the data, where R -Square (R-Sq) which called determination coefficient describes the amount of variation in the observed response that is explained by the model, adjusted R-square (R-Sq (adj)) is a modified R that has been adjusted for the number of terms in the model, and predicted R-square (R-Sq (pred)) reflects how well the model will predict future data. Higher values of R

-Square (R-Sq) and adjusted R-square (R-Sq (adj)) indicate a better fit, as shown in Table 7. The main effects plot to visualize the effects graphs the MRR mean for each factor level, as shown in Figure 12. Main effects plot for MRR shows that:

1. Current has the strongest effect on MRR followed by duty factor and electrode shape.
2. Flat electrode produces highest MRR while conical and round electrode produces similar MRR because of higher active area.
3. MRR increases with increasing current because of strong spark.
4. MRR increases with increasing duty factor but after a certain value of (0.8) it reduces slightly because of plasma channel expansion.

Table 7: Model summary for MRR.

S	R-sq	R-sq (adj)	R-sq (pred)
1.8196	98.5 %	95.11 %	82.87 %

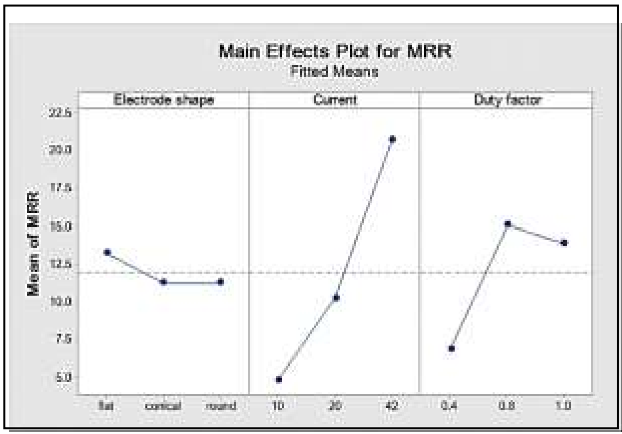

Figure12: Main effect s plot for MRR

6. Conclusions

The main conclusions can be summarized as follows:

1. The maximum value of MRR is (31.181 mm^3/min) and minimum value is (2.667 mm^3/min) in flat electrode.
2. The maximum value of MRR is (26.098 mm^3/min) and minimum value is (3.398mm^3/min) in conical electrode.
3. The maximum value of MRR is (25.016 mm^3/min) and minimum value is (2.38 mm^3/min) in round electrode.
4. From experimental work, it is found that for most of experiments flat electrode produces highest MRR due to higher active area including all surface area between the flat electrode and work piece as compared to conical and round electrodes (with ratio of 119 % and 125 %), respectively. From factorial plot, it is clear that current has the strongest influence on MRR followed by duty factor and electrode shape with percentage contribution of 67.98 %.
5. From Minitab Statistical Software it is revealed that factorial design model can predict the MRR values with a good accuracy of R -Square (R-Sq) of 98.50%.

References

[1] S. Assarzadeh and M. Ghoreishi, "Statistical modeling and optimization of process parameters in electro-discharge machining of cobalt-bonded tungsten carbide composite (WC/6%Co)," The Seventeenth CIRP Conference on Electro Physical and Chemical Machining (ISEM), Vol. 6, pp. 464-469, 2013.

[2] D.N. Mishra, A. Bhatia and V. Rana, "Study on Electro Discharge Machining (EDM)," The International Journal of Engineering and Science (IJES), Vol. 3, pp. 24-35, 2014.

[3] S.H. Aghdeab and V.N. Najm, "The Influence of Current & Pulse off Time on Material Removal Rate and Electrode Wear Ratio of Steel 304 in EDM," Engineering and Technology Journal, Vol. 33, Part (A), No. 8, 2015.

[4] S.H. Aghdeab and I.A. Qasim, "Analysis of the Influence of Different EDM Parameters Using Taguchi Technique," Engineering and Technology Journal, Vol. 35, Part A, No. 6, 2017.

[5] V. Srivastava and P.M. Pandey, "Statistical Modeling and Material Removal Mechanism of Electrical Discharge Machining Process with Cryogenically Cooled Electrode," International Conference on Advances in Manufacturing and Materials Engineering, Vol. 5, pp. 2616-2620, 2011.

[6] K.H. Howard, R. Hoseinnezhad, J. Mo and M. Brandt, "A Survey of Control Methods for Electrical Discharge Machining Process," Journal of Electrical and Electronic Engineering, Vol. 6, pp. 7-28, 2013.

[7] B. Singh, C.D. Singh, and J. Singh, "Improving the Process Capabilities of EDM: A Review," International Journal of Emerging Technologies in Computational and Applied Sciences (IJETCAS), Vol. 12, pp. 115-119, 2015.

[8] S.H. Aghdeab and L.A. Mohammed, "Experimental Investigations of Hole - EDM to Optimize Electrode Wear through Full Factorial of Design of Experiment," Engineering and Technology Journal, Vol. 31, Part (A), No. 13, 2013.

[9] M. Shabgard, M. Seyedzavvar and S.N.B. Oliaei, "Influence of Input Parameters on the Characteristics of the EDM Process," Journal of Mechanical Engineering, Vol. 9, pp. 689-696, 2011.

[10] A.I. Ahmed and S.H. Aghdeab, "Effect of Pulse On / Off Time and Current on Material Removal Rate and Electrode Wear Ratio in Electrical Discharge Machining (EDM)," M.Sc. Thesis, Department of Production Engineering and Metallurgy, University of Technology, Baghdad, Iraq, 2016.

[11] N. Mathew and D. Kumar, “Study of Tool Wear Rate of Different Tool Materials During Electric Discharge Machining of H11 Steel at Reverse Polarity,” International Journal of Mechanical Engineering and Robotics Research, Vol. 3, No. 3, 2014.

[12] S. Daneshmand, E.F. Kahrizi, E. Abedi, and M.M. Abdolhosseini, “Influence of Machining Parameters on Electro Discharge Machining of NiTi Shape Memory Alloys,” International Journal of Electrochemical Science, Vol. 8, pp. 3095-3104, 2013.

[13] V. Srivastava and P.M. Pandey,” Performance Evaluation of Electrical Discharge Machining (EDM) Process Using Cryogenically Cooled Electrode,” Journal of Materials and Manufacturing Processes, Vol. 27, pp. 683–688, 2012.

[14] C. Gnanavel, R. Saravanan, M. Chandrasekaran, and R. Pugazhenthi, “Restructured Review on Electrical Discharge Machining- A State of the Art,” International Conference on Emerging Trends in Engineering Research, Vol. 183, 2017.

[15] M. Kalantari and H. Najafyan, “Effect of Input Parameters on the Depth of the Heat Affected Zone (HAZ) AISI H13 Steel Electrical Discharge Machining Process (EDM),” Journal of Archives of Civil and Mechanical Engineering, Vol. 27, pp. 7-11, 2016.

[16] A. Singh, P. Kumar and I. Singh, “Electric Discharge Drilling of Metal Matrix Composites with Different Tool Geometries,” Journal of Engineering Manufacture, Vol. 227, pp. 1245-1249, 2013.

Author’s biography

Shukry Hammed Aghdeab, Ass. Prof. Dr.Shukry H. Aghdeabrecived his B.Sc. M.Sc. degrees in 1994, 2000 and 2008 and Ph.D. in production engineering from the University of Technology, Iraq. He has published many papers international conference and journals in the field of cutting materials for electrical discharge machining and others.

Nagham Ghanem Ghazy was born in Baghdad, Iraq in January 1994. She received her B.Sc. and M.Sc. in production engineering from University of Technology, Iraq in 2015 and 2018 respectively. Her research interests are metal cutting processes with non-traditional cutting machine like electrical discharge machining.