Eng. &Tech.Journal, Vol.33,Part (A), No.8, 2015

The Influence of Current & Pulse off Time on Material Removal Rate and Electrode Wear Ratio of Steel 304 in EDM

Dr. Shukry Hammed Aghdeab
Metallurgy & Production Engineering Department, University of Technology/ Baghdad
Email:shukry-hammed@yahoo.com
Vian Nihad Najm
Email:vean.nihad@gmail.com
Metallurgy & Production Engineering Department, University of Technology/ Baghdad

Received on:2/11/2014 & Accepted on:2/4/2015

Abstract

EDM (Electric Discharge Machining) machine was used for machining of conducting cutting materials such as steel 304 in dielectric solution (diesel fuel) by supplied by DC current values (10, 20, 30, 42 and 50A). Voltage of (140V) was used to cut (1) mm thickness.

The experimental results reveal that the material removal rate enhanced by increasing the current values also show that the Electrode wear ratio rises with increase in the current values. It is also concluded that the material removal rate reduces with increasing the pulse off time values and the electrode wear ratio.

Key-words: EDM, Material removal rate (MRR), Electrode wear ratio (EWR).

تأثير التيار و زمن توقف النبضة على معدل ازالة المعدن ومعدل بلى العدة لفولاذ 304 في التشغيل بالشرارة الكهربائية.

الخلاصة

أستخدمت ماكنة التشغيل بالتفريغ الكهربائي لقطع المواد الموصلة مثل الفولاذ 304 في محلول عازل (وقود الديزل) بتسليط قيم تيار مستمر (10, 20, 30, 42 and 50A). الفولتية المستخدمة 140V لقطع سمك 1mm من فولاذ 304.

نتائج هذه التجربة تبين ان معدل ازالة المعدن يتحسن بازدياد قيم التيار الكهربائي وان معدل بلى العدة يزداد بازدياد التيار الكهربائي. و لقد استنتج ايضا ان معدل ازالة المعدن يقل بازدياد زمن توقف النبضة بينما معدل بلى العدة يزداد.

INTRODUCTION

Electrical discharge machining (EDM) is one of the most extensively used non-conventional material removal processes. Its unique feature is using thermal energy to machine electrically conductive parts regardless of hardness [1]. In this electro-thermal process, the material is removed by erosive action of electric discharges occurring between a tool electrode, mostly made of copper or graphite, and a workpiece of steel or ceramic. Both workpiece and tool electrode are submerged in a fluid called dielectric [2]. EDM is used in a large number of industrial areas: automotive industry, electronics, domestic appliances, machines, packaging, telecommunications, watches, toys, aeronautic and surgical instruments.

https://doi.org/10.30684/etj.2015.108827
2412-0758/University of Technology-Iraq, Baghdad, Iraq

Principle of EDM Process

The principle of EDM is simple. The workpiece and tool are placed in the working position in such a way that they do not touch each other. They are separated by a gap which is filled with an insulating fluid. The cutting process therefore takes place in a tank. The workpiece and tool are connected to a (DC) source via a cable [3]. Material is removed by heat. Heat is introduced by the flow of electricity between the electrode and workpiece in the form of a spark. Material is placed at the closest points between the electrode and workpiece, where the spark originates and terminates, are heated to the point where the material vaporizes as shown in Fig. (1) [4].

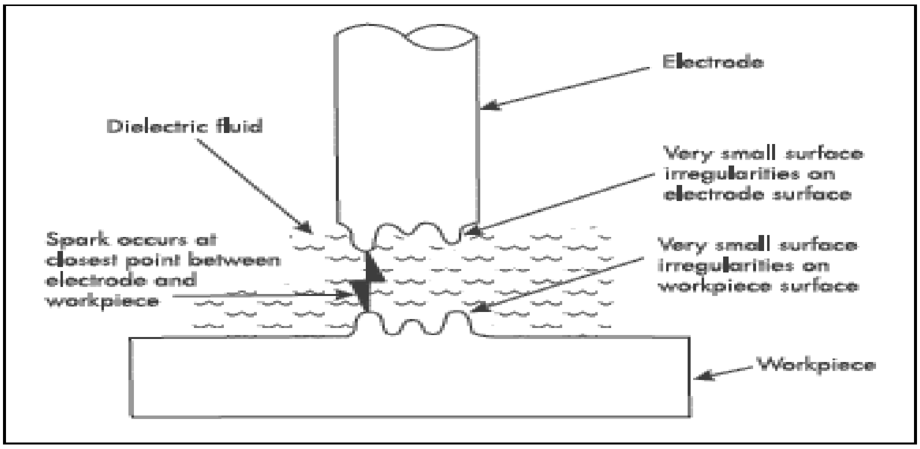
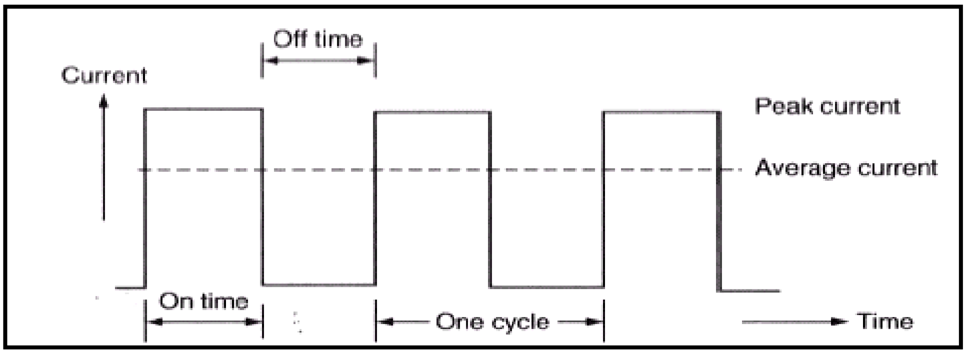


Figure (1). Sparking occurs at closest points [4].

The electrode and workpiece are connected to a suitable power supply. The power supply generates an electrical potential between the two parts[5].

As the voltage is built up, at some predetermined value, electrons break loose from the tool (cathode) and are impelled towards the work anode. During their travel within the electrode space, the electrons collide with the neutral molecules of the dielectric causing ionization. When the ionization becomes sufficiently strong, a momentary current impulse or discharge passes through the gap. This is accompanied by the generation of extremely high temperature (usually of the order of 8000 to 12000 °c) causing vaporization of the metal at the point of discharge [6].

A series of voltage pulses Fig.(2) of magnitude about (20) to (120) V and frequency on the order of (5) kHz are applied between the two electrodes, which are separated by a small gap, typically (0.01) to (0.5)mm. When using relaxation circuit (RC) generators, the voltage pulses, as shown in Fig.(3), are responsible for material removal [7] The removal of material is caused mainly by a thermal phenomenon, by fusion and vaporization of metal [4].



Figure(2). Typical EDM pulse current train for controlled pulse generator [7].

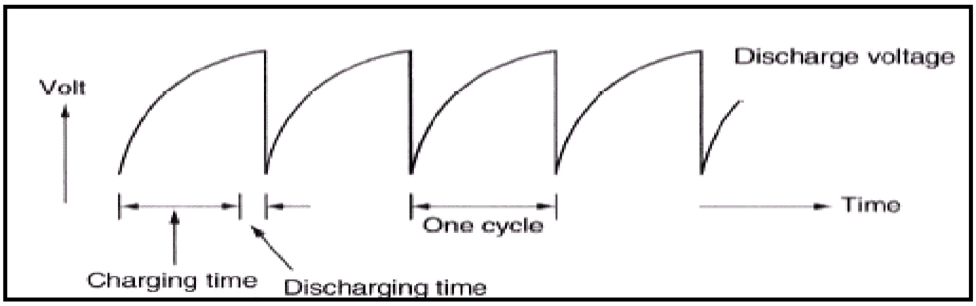


Figure (3). Variation in voltage with time using an RC generator [7].

Electrode wear (EW)

Erosion with a light current gives a low rate of removal, while conversely a heavy current gives a high rate of removal. But the wear on the tool electrode expressed as a percentage of the volume also increases if steel workpieces are eroded with copper electrodes. Graphite electrodes behave differently. The wear declines up to a certain current level and then remains more or less constant. Eroding with short pulses means increasing electrode wear. Conversely the wear is smaller when the pulses are long [3]. The electrode wear also depends on the dielectric flow in the machining zone. If the flow is too turbulent, it results in an increase in electrode wear. Pulsed injection of the dielectric has enabled reduction of wear due to dielectric flow [8].

$$EWR=\frac{WBM-WAM}{WBM}\times 100\% \qquad ....(1)$$

Where:
EWR= Electrode wear rate (%).
WBM= Weight of electrode before machining (g).
WAM= Weight of electrode after machining (g).

Metal Removal Rate (MRR)

The amount of metal removed by a single discharge is proportional to the diameter of crater and depth of which the melting temperature is reached. The spark is considered as a uniform circular heat source on the electrode surface and the diameter of this circular source remains constant. Further the rate of heat input remains constant during the period of discharge duration [9]. MRR depends on the properties of the dielectric fluid used in the EDM as much as it depends on the properties of the workpiece material and the electrode. Minimum wear of the electrode that removes the materials from the workpiece by conducting the current is required in EDM applications [5]. The MRR of the workpiece will be measured by dividing the weight of workpiece before and after machining (found by weighing method using balance) against the machining time that was achieved [8].

$$\mathrm{MRR} = \frac{\text{weight of material removed from the workpiece}}{\text{mahining time}} \qquad \ldots(2)$$

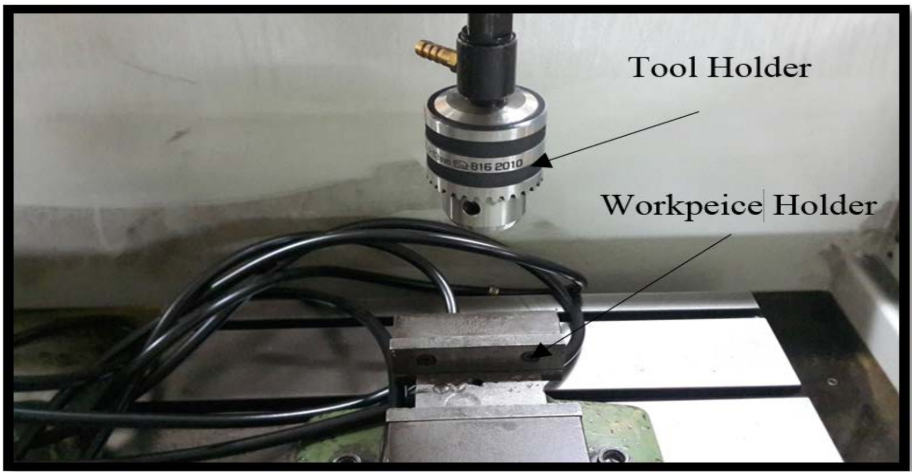
$$\mathrm{MRR} = \frac{\mathrm{WPVB} - \mathrm{WPWA}}{\mathrm{MT}}$$

Where:
MRR= Material removal rate (g/min)
WPVB= Weight of the workpiece before machining (g).
WPWA= Weight of the workpiece after machining (g).
MT = Machining time (min).

Experimental Procedure

The metal removal was carried out using CHMER EDM machine, as shown in Fig.(4) and fig.(5) In the experiment a copper electrode was used and steel 304 was used as workpiece material of (1mm) thickness, table (1) shows the mechanical, physical properties and Table (2) shows chemical composition of steel 304.

Figure (4) CHEMER EDM machine model (CM 323C).



Figure(5). CHEMER EDM machine holders.

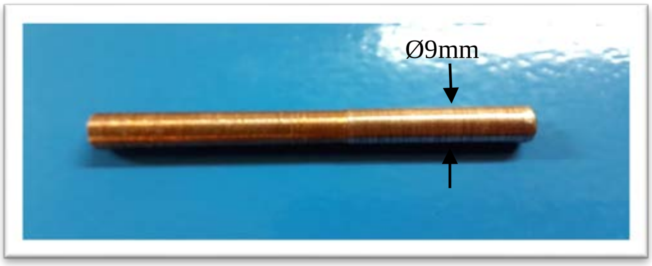
Table (1) Mechanical and physical properties of Steel 304.

physical Properties	steel 304 AISI
Tensile Strength (MPa)	600
Compression Strength (MPa)	210
Thermal conductivity (W/cm.K)	0.162
Electrical conductivity ($\times 10^5/\Omega$ cm)	11.6
Melting point (K)	1644
Modulus of Elasticity (GPa)	193
Hardness (HRB)	88
Yield strength (MPa)	241

Table (2) Chemical composition of steel 304.

Material	C%	Si%	Mn%	P%	S%	Cr%	Mo%	Ni%	Cu%	V%
weight %	0.043	0.3	1.52	0.03	0.0005	19.4	0.222	8.60	0.33	0.064
	W%	Fe%								
	0.059	Balance								

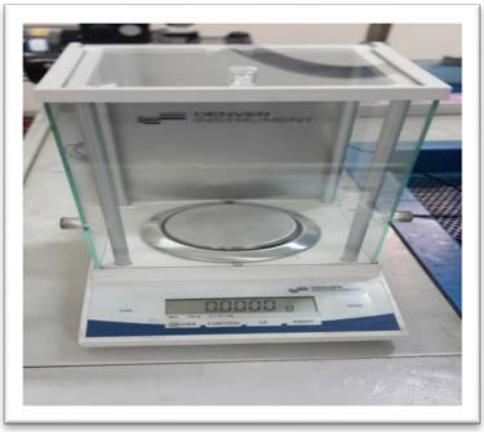
In the experiment a copper electrode with Ø 9 mm diameter was used, the copper electrode was machined in a lathe turret to get the desired dimensions as shown in Fig.(6).



Figure(6). Copper electrode before machining.

All experiments were carried out with the same electrode and oil diesel as dielectric fluid. The electrode was fixed into the chuck. After that the level was checked to avoid some manual error during fixing the electrode. Then the workpiece was placed in the workpiece holder.

Both workpiece and electrode in each test procedure were weighted before and after machining using sensitive balance type (DENEVER INSTRUMENT 4Dig.), shown in Fig.(7), and recorded.



Figure(7). Sensitive balance machine.

Pulse current was varied (10A-20A-30A-42A-50A) and pulse interval was varied (25µs-35µs-75µs-100µs), and all other input parameters, pulse on time and voltage were kept constant. Fixed input variables in first set of experiments were: T-on = 75µs and voltage = 140 V, table (3) shows the machining parameters used in the experimental work.

Table (3) Machining parameters used in experimental work.

Working Parameters	Description
Workpiece	Steel 304 (1.5mm)
Tool-electrode material	copper (5mm diameter)
Tool-electrode speed	20 r.p.m.
Shape of tool-electrode	Cylindrical bar (conical)
Tool-electrode polarity	Negative (-)
Workpiece polarity	Positive (+)
Dielectric	Diesel fuel
Dielectric temperature	40-80°C
Input voltage	380V (three phase) AC
Output voltage	140V (two phase) DC
Current	10-50A

Analysis

Adaptive Neuro-Fuzzy Inference System (ANFIS)

This work proposes a method using an Adaptive Neuro-Fuzzy Inference System (ANFIS) in order to predict material removal rate and electrode wear ratio using cutting parameter (Current) in relation to different variables. ANFIS method constructs a fuzzy inference system, using a given input and output data set. For this model, main parameter for the experiments is discharge current (I) the (input data set) and material removal rate MRR and electrode wear ratio (output data set). The training dataset are obtained from experiments. Training process was accomplished by using Matlab. The training epoch for each network is 20, hybrid method optimization, the ANFIS model prediction was made with the Gaussian membership type (gaussmf), given the training error for predicting material removal rate (5.569e-008), and for the electrode wear ratio training error (2.6125e-008). When the network training was successfully finished, the ANFIS was tested with validation data.

Results and Discussion

Fig.(8) shows the effect of current on material removal rate using copper electrode and steel 304 as a workpeice material with (1 mm) thickness with different current values. It is obvious that erosion with light current gives a low rate of removal, conversely a heavy current gives a high rate of removal. This is due to the fact that at low current a small quantity of heat is generated and utilized in melting and vaporizing a small quantity of material. The highest material removal rate is (0.18904) g/min with highest current value (50A) and lowest material removal rate is (0.04187) g/min with less current value (10A) and the material removal rates (0.08655, 0.154833 and 0.1723) g/min are achieved respectively for currents values of (20, 30 and 42 A).

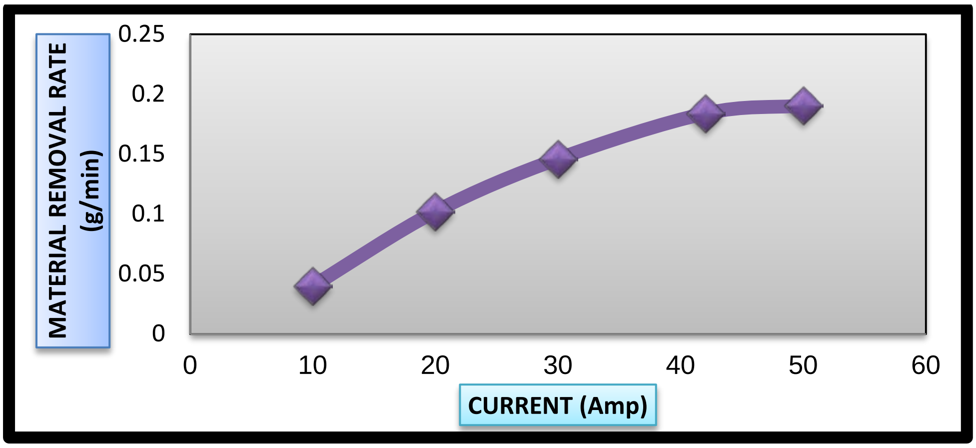
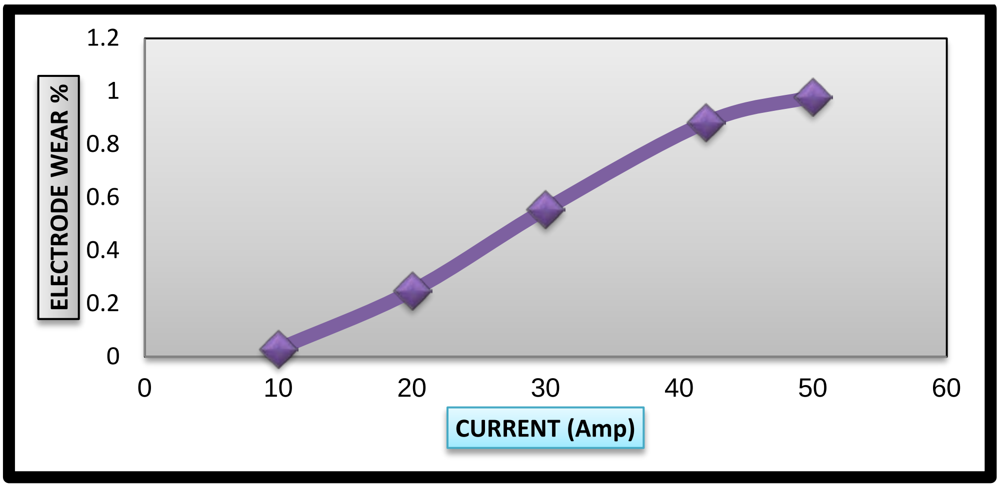


Figure (8) The effect of current on material removal rate (MRR).

Fig.(9) presents the influence of current on electrode wear ratio (EWR) using copper electrode and steel 304 as workpeice material of (1 mm) thickness with different current values, It can be observed from this graph that electrode wear ratio increases with increase in current values. This means that machining with higher values of discharge current produces higher heat energy exerted on both electrodes. The molten and ejected metal from both of them will increase. The electrode wear ratio are (0.02665%, 0.222%, 0.410447%, 0.57395% and 0.71213%) for current values (10, 20, 30, 42 and 50A) respectively.



Figure(9). The effect of current on electrode wear ratio.

Fig.(10) shows the effect of pulse off time on material removal rate using copper electrode, steel 304 as a workpiece material of (1mm) thickness and the fixed input variables are pulse on time (75µs),current (30A). This figure reveals that the Material Removal Rate (MRR) decreases almost linearly with increases in the pulse off time. This can be due to the increase in pulse off time which reduces the intensity of current discharges which is given in a certain period (pulse on time) as it is concluded in Refs [10and 11]. It can be observed when pulse off time is (25µs), material removal rate is (0.025696) g/min, When pulse off time is (37µs), material removal rate is (0.023733) g/min, When pulse off time is (75µs) material removal rate is (0.021495) g/min and when pulse off time is (100µs) material removal rate is (0.016889) g/min.

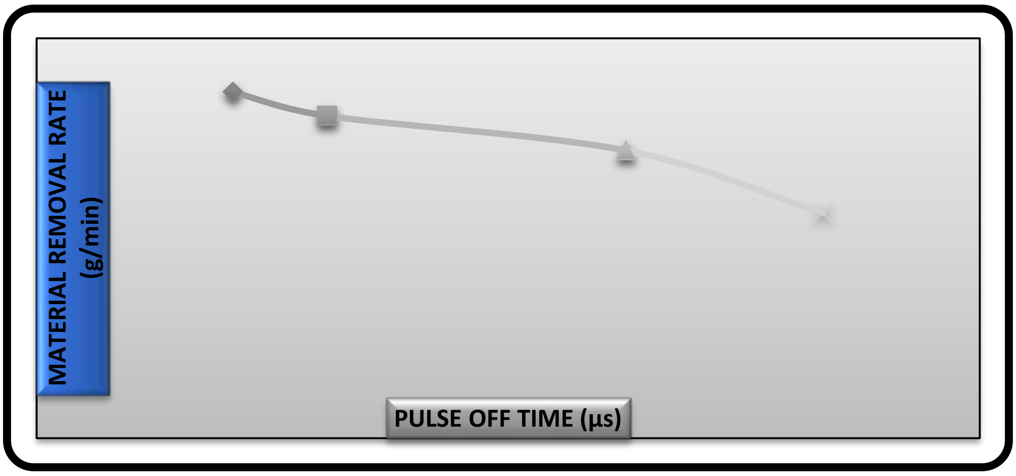


Figure (10) The influence of pulse off time on material removal rate (MRR).

Fig.(11) shows the effect of pulse off time on electrode wear ratio using copper electrode, steel 304 as workpiece material of (1mm) thickness and the fixed input variables are pulse on time (75µs) and current (30A). This figure reveals that the electrode wear ratio (EWR) increases with the increase in the pulse off time, this is may be due to the reason that the pulse off time is the time required for the reestablishment of insulation in the working gap or deionization of the dielectric at the end of each discharge duration. At short pulse off time EWR is less due to the fact that with short pulse off time the probability of arcing is very high, because the dielectric in the gap between the workpiece and electrode cannot be flushed away properly and the debris particles still remain in discharge gap and this results in arcing, due to which the EWR decreases. With increase in pulse off time, better flushing of debris take place from the inter-electrode gap, resulting in increase in the EWR as it is concluded in Refs [10]. It can be observed when pulse off time is (25µs) electrode wear ratio is (0.44405%). when pulse off time is (37µs), electrode wear ratio is (0.44954%). when pulse off time is (75µs), electrode wear ratio is (0.473%) and when pulse off time is (100µs), electrode wear ratio is (0.507121%).

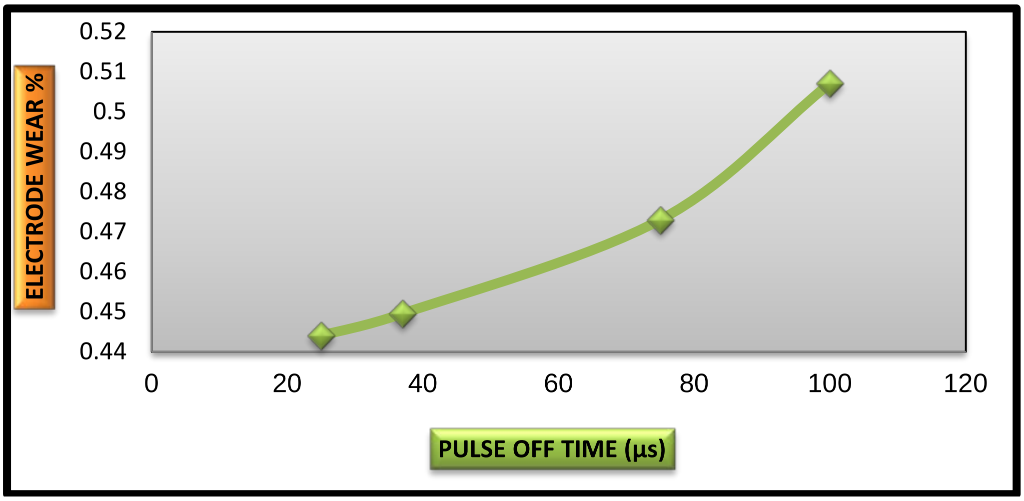
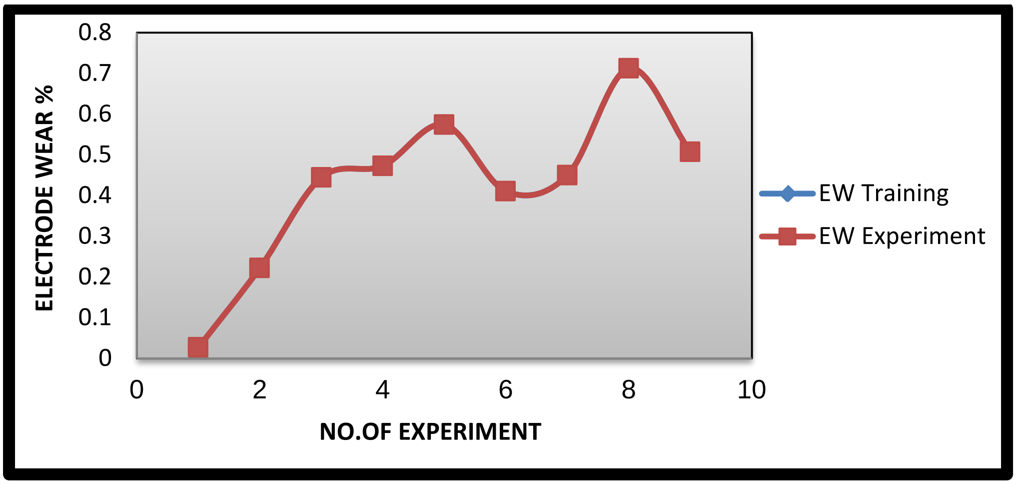


Figure (11) The influence of pulse off time on electrode wear ratio (EWR).

Fig.(12) shows the compared and predicted values obtained by ANFIS model with those obtained and estimated from the experiment. The ANFIS predicted electrode wear ratio values show a fine comparison with those obtained experimentally. (prediction error =2.6125e-008). It is evident that the fuzzy logic technique can help to get better prediction of the experimental data.



Figure(12) Correlation between experimental EW and ANFIS training values of EW.

Fig.(13) shows the compared and predicted values obtained by ANFIS model with those obtained and estimated from the experiment. The ANFIS predicted material removal rate values show a fine comparison with those obtained experimentally. (prediction error =5.569e-008). It is evident that the fuzzy logic technique can help to get better prediction of the experimental data.

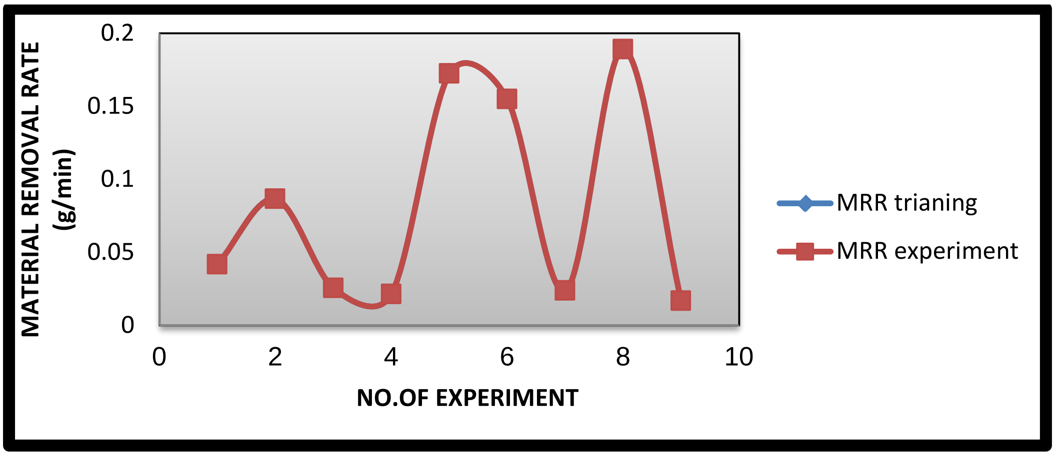


Figure (13) Correlation between experimental MRR and ANFIS training values of MRR.

Fig.(14) makes it obvious the 3D surface profile obtained during neuro- fuzzy modeling and shows the influence of the machining parameters (discharge current and pulse interval) on the electrode wear ratio.

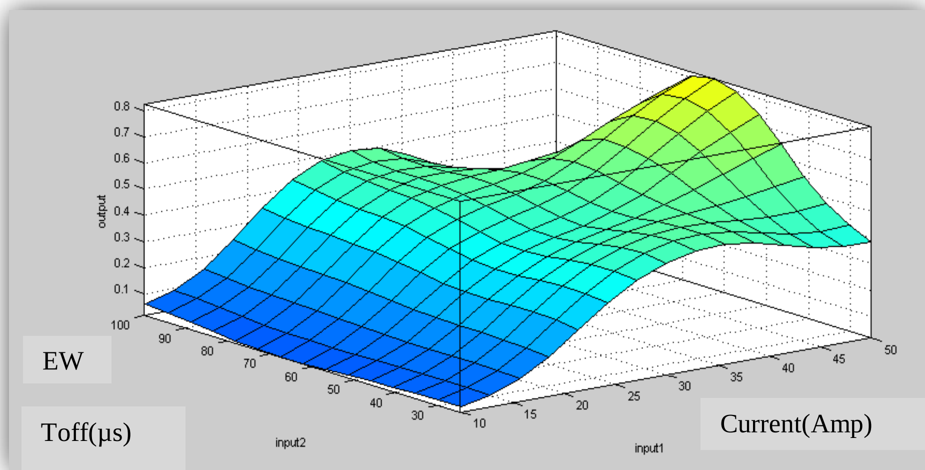


Figure (14) 3D plot, the influence of the pulse off time and current on electrode wear.

Fig. (15) makes it obvious the 3D surface profile obtained during neuro- fuzzy modeling and shows the influence of the machining parameters (discharge current and pulse interval) on the material removal rate.

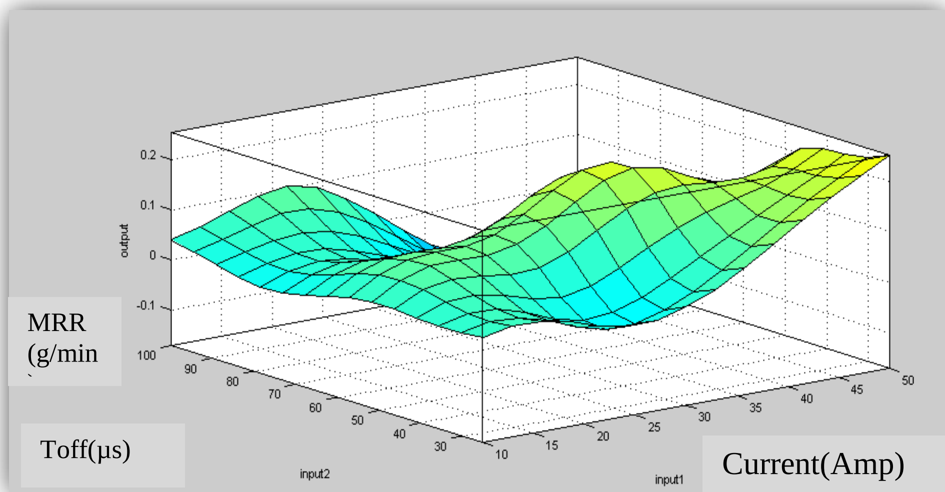


Figure (15)3D plot, the influence of the pulse off time and current on material removal rate.

Conclusions

In this study, the main conclusions which can be summarized as follows:

1-The experimental results reveal that the material removal rate is enhance by increase in the current values also show that the Electrode wear ratio rises with increase in the current values.

2- It was noticed that the maximum value of the material removal rate is (0.18904) gm/min with highest current value (50A)

3- It was noticed that the minimum value of the electrode wear ratio is (0.02665%) with current value (10A).

4-It is concluded that the material removal rate reduces with increasing in the pulse off time values and the electrode wear ratio increases with increase in the pulse off time values.

5- The results also indicate that the ANFIS model could predict the output response with a good accuracy for material removal rate and for electrode wear ratio even when using the limited experimental data for training purpose. The ANFIS is recognized by simplicity in design and faster learning and is found suitable for the EDM process model development.

References

[1]. Ho, K., H., and Newman, S., T., "State of The Art Electrical Discharge Machining (EDM)", International Journal of Machine Tools and Manufacture, Vol. 43, pp. 1287-1300, 2003.

[2].Hoang Vinh Sinh, "A Method to Reduce The Relative Wear in EDM Die Sinking Processes By Reversed Pulse", Department of Industrial Automation, Hanoi University of Technology, 2004.

[3]. Manfred Storr, "Important Facts About Spark Erosion", Human Technology for man, environment and machines, pp.6-8, 2007.

[4].Elman C. Jameson, "Book: Electrical Discharge Machining", Society of Manufacturing Engineers, pp.1-3, 2001.

[5]. A. Anders, "Tracking Down The Origin of Arc Plasma Science, I. Early Pulsed and Oscillating Discharges", IEEE Trans. Plasma Sci., pp. 1052–1059, 2003.

[6]. P. C. PANDEY and C. K. SINGH, "Production Engineering Sciences", Standard Publishers Distributors, P 361, 1984.

[7].Hassan El-Hofy, "Advanced Machining Processes: Nontraditional and Hybrid Machining Processes", Mechanical Engineering Series, Vol-1, pp.115-118, 2005.

[8]. S.H.Tomadi, M.A.Hassan, Z. Hamedon, IAENGR.Daud and A.G.Khalid, "Analysis of the Influence of EDM Parameters on Surface Quality, Material Removal Rate and Electrode Wear of Tungsten Carbide", Proceedings of the International Multi Conference of Engineers and Computer Scientists, Vol-2, pp.978-988, 2009.

[9]. R. K. Jain, "Production Technology", Khanna Publishers, PP. 548-549, 2009.

[10]. Parmod Malhotraand and Amit Kohli, "Performance Study of Electrical Discharge Machining With H-11 Tool Steel Using One Variable at a Time Approach", International Journal for Science and Emerging, Vol-12, pp.15-20, 2013.

[11]. Sanjay Kumar Majhi, T.K.Mishra, M.K.Pradhan and Hargovind Soni, " Effect of Machining Parameters of AISI D2 Tool Steel on Electro Discharge Machining", International Journal of Current Engineering and Technology, Vol-4, 2014.