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Research Article

Modeling and Analysis of Electric Discharge Machine Parameters using Neural Network

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Abstract

In this research, a neural network was used to develop a model of EDM process and analysis of variance (ANOVA) method was used to analyze the results. The pulse current(Ip), pulse time(Ton) and pulse of time (Toff) were selected as input to the neural network while material removed rate(MRR), tool wear rate(TWR) and surface roughness(Ra) represent the output of this neural network. Data obtained from practical experiments are used for training and testing the neural network. The effect of change in machining conditions on process performance can be tested and analyzed through the neural network model. Three models of neural networks were obtained. The first model predicts the rate of the removed metal, the second model predicts the wear rate of the tool and the third model predicts the roughness of the surface. The results indicate that the neural network model can predict the operation performance with reasonable accuracy for different machining conditions.

***Keywords**: Electro-discharge (EDM), Artificial neural network(ANN), Levenberg-maquardt (trainlm), ANOVA.*

Introduction

Electric discharge machining or corrosion spark, EDM is one of the most important non-traditional methods of metal removal when the machining process obtained for electrically conductive materials regardless of hardness and strength of these materials (T. Modi *et al*, 2015). The result of the process corrosion resulting from the electrical discharge between the tool and the work piece and there is a gap between the work piece and the tool about the thickness of a human hair ,this gap can be controlled by the servo system and both the tool and the work piece immersed in liquid(oil ,kerosene, deionized water), the work metal becomes an anode and the tool is a cathode within a short period of about 10 microseconds, the voltages are large enough to generate the spark. When electrons and positive ions reach both anode and cathode, kinetic energy is produced in the form of heat (T. Raut *et al*, 2015).

The relationship between process variables (input) and response variables (outputs) during the EDM process is a random, nonlinear relationship in nature. To establish a relationship between the input and output variables, these relationships are either empirical relationships or non-linear regression. We will address the use of the neural network (ANN) in the modeling of EDM machine variants. This modeling process will reduce the effort and save a lot of money, time and optimal efficiency. A lot of investigations have been conducted in this field using neural network modeling (Angelos *et al*, 2008).

Panda and Bhoi(Deepak Kumar *et al*, 2005)has developed an ANN model (using feed forward neural architecture) using Levenberg-Marquardt learning algorithm and logistic sigmoid transfer function to predict the material removal rate. Here they have considered the process parameters gap voltage, pulse duration and pulse interval. To evaluate the performance of ANN model sum square error and R square coefficients were used and the validity of the neural network model was checked with the experimental data.

Principle of EDM

The result of the process of corrosion resulting from the electrical discharge between the tool used and the piece of work and there is a gap between the work piece and the tool ranging from (0.025-0.050) mm ,this gap can be controlled by the servo system and both the tool and the piece of work immersed in liquid(oil ,kerosene, deionized water) show below in the figure(1) and figure(2)(Elman *et al*, 2001).

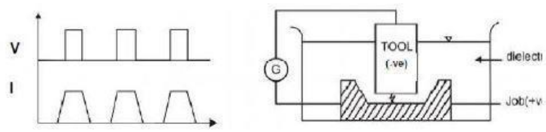

Figure 1 Mechanism of EDM processes

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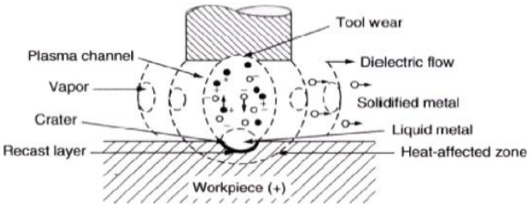


Figure 2 EDM Spark descriptions

Important parameters of EDM

Here is a list of important parameters of EDM process:
(a)Spark On-time (pulse time or Ton): Its the period of time required to flow current during the cycle and measured by microsecond. The rate of the metal removed is directly proportional to the energy applied during this period.
(b) Spark off time (pause time or Toff): Its the time period in which the molten metal is allowed to solidified out of the gap, and this period is measured by microseconds.
(c) Arc gap (or gap): Is the distance between the electrode and the working piece.
(d) Discharge current (Ip): Is the current measured by the ampere allowed during the cycle.
(e) Duty Cycle: The percentage of the time period (Ton) to the total time period(Ton +Toff).
(f) Voltage (v): Is the voltage difference measured in volts and it affects the rate of the metal removed.

Objective of the present work

The aim of this project is develop a neural network model for correlating the various machining parameters, such as pulse on time, pulse off time ,peak current on the most dominant machining criteria,i.e the metal removal rate, electrode wear ratio, surface finish ,for achieving controlled EDM. Also analyze the results using analysis of variants (ANOVA) method.

Experimental works

Machine tool: In this research, the electric discharge machine (EDM-435L) sinking machine is used as shown in the figure (3) below. This machine is located in the workshops of the college of Engineering/ University of Thi –Qar. The liquid used in this machine is a mixture of oil (kerosene and gasoline). All experiments were performed on this machine.

Figure 3 EDM machine Tool

Figure 4 Samples before work on EDM machine

Figure 5 Samples after the work on EDM machine

Figure 6 Samples of the copper electrode

Design parameter

There are several design parameters of EDM process we choose the following design parameters:

1. Material removal rate(MRR) =(w1-w2)/t(gr/min).
2. Tool wear ratio (TWR)=(E1-E2)/t(gr/min).
3. Surface roughness (SR).

w1=weight of sample before machining; w2=weight of sample after machining.
E1=weight of copper electrode before machining; E2=weight of copper electrode after machining.
t=machining time (min), in this work take t=12 min for each sample.

Measurements

Weighing machine: The weight of work piece and tool has taken by high precision balance, brand: DENVER INSTRUMENT as shown in the figure (9). The balance capacity is 220 gram and accuracy is 0.0001g.

Figure 7 Electronic Balance Weight Machine

Technical Roughness Tester PCE-RT 1200: Roughness is defined of the arithmetic value of the profile from centerline along the length and can be express as:

Ra=1/L∫|y(x)|d(x)||

Where L is the sampling length, y is the profile curve and x is the profile direction. The average 'Ra' is measured with in L=0.8mm.

Table 1: Roughness measuring condition

Dimensions	140mmx52mmx48mm (without probe)
Radius of probe pin	5μm(default),2μm
Material of probe pin	Diamond
Probe pin angle	90
Sampling length(L=0.8)	Vt=0.5mm/s

Figure 8 Measure the surface Roughness of Sample

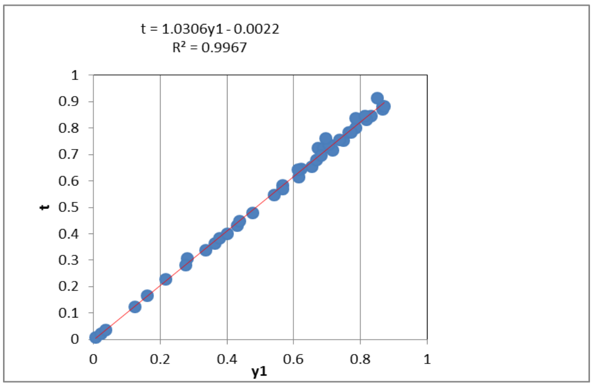
Neural Network Technique

The relationship between process variables (input) and response variables (outputs) during the EDM process is a random, nonlinear relationship in nature. To establish a relationship between the input and output variables, these relationships are either empirical relationships or non-linear regression. We will address the use of the neural network (ANN) in the modeling of EDM machine variants. This modeling process will reduce the effort and save a lot of money, time and optimal efficiency.

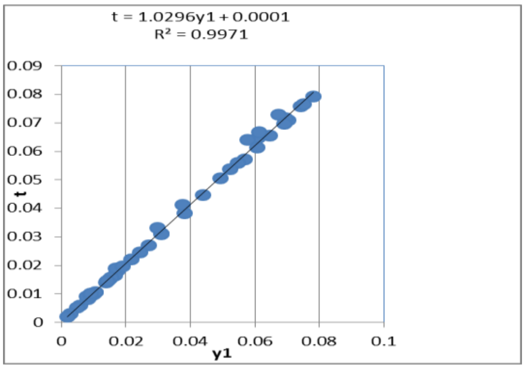
In this study, three neural networks were used, so that for each variable of the response to a particular neural network. The inputs are the current (Ip) and pulse time(Ton), pulse off time (Toff). Each neural network is trained on special data in addition, a link was obtained between the incoming and outgoing variables of the neural network. After the completion of training of each neural network and obtaining a relationship for each neural network, a link was obtained between these three neural networks.

Results

In present work, ANN are used to modeling the EDM process then the analysis of variance (ANOVA) method are used to analysis the effect of three parameters (Ton, Toff and Ip) on three variables (MRR, TWR and Ra). In this research three models were used the first model linked between the machining process variables (Ton, Toff, Ip) and the rate of the removed metal, the greatest error obtained in this model was 8.34%. The second model linked between the variables of the machining process and the tool wear, the greatest error obtained in this model was 13%. The third model is used to predict the roughness of the surface and the greatest error obtained in this model was 7.14%. A relationship has been established between these three models was obtained to predict both the rate of the metal removed, the rate of wear of the tool and the rate of surface roughness. In this paper, the values of Regression value were obtained, these values for the metal removed were (R^2 = 0.9976), the wear of the tool (R^2=0.9981) and the surface roughness rate was (R^2= 0.9971) this high Regression values confirm the accuracy of the results used as shown in figures (9,10,11).



(a)



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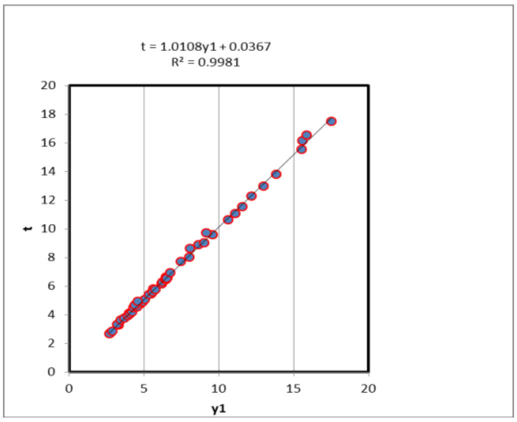
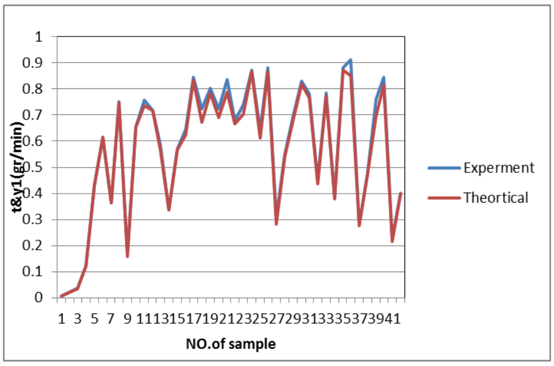
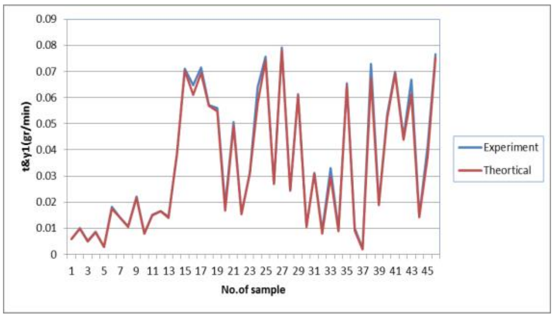


(c)

Figure 9 Linear regression analysis between NN results and experimental results (a.MRR, b.TWR, c.SR)



(a)



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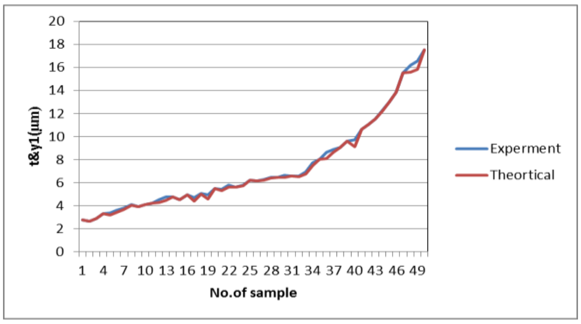
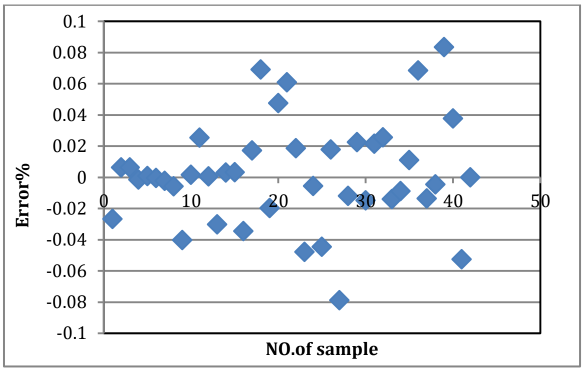
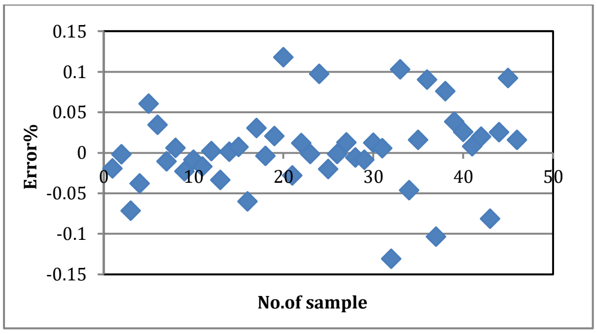


(c)

Figure 10 Relation between NN results and Experimental works (a.MRR,b.TWR,c.SR)



(a)



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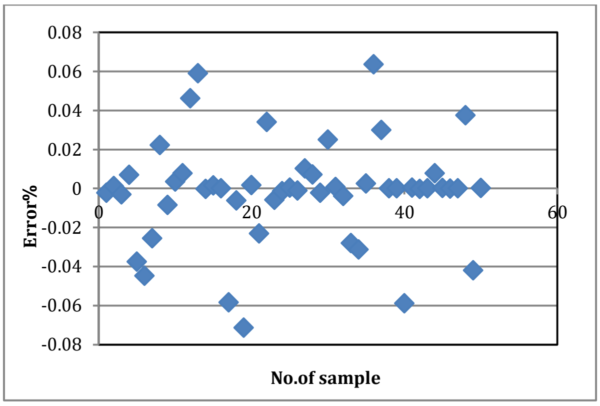

(c)

Figure 11 Error in each sample (a.MRR,b.TWR,c.SR)

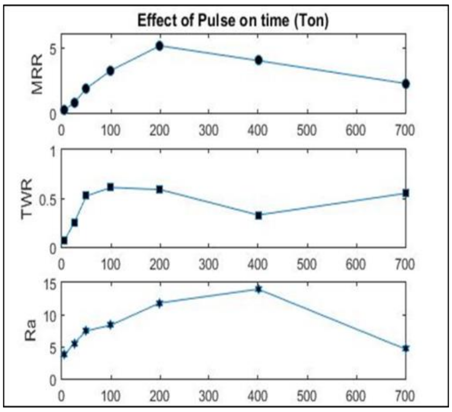

Figure 12 Effect of pulse on time (Ton) on the MRR,TWR,SR

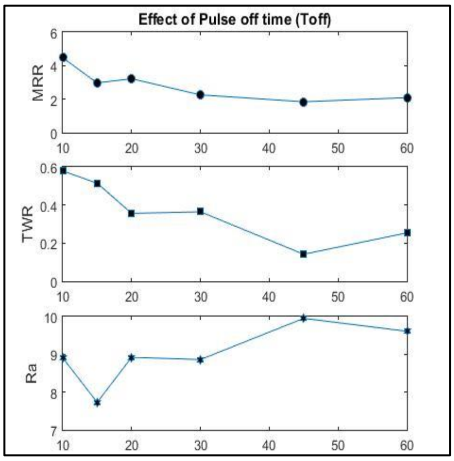

Figure 13 Effect of pulse off time (Toff) on the MRR,TWR,SR

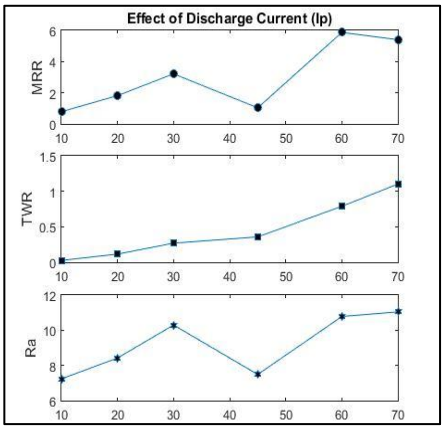

Figure 14 Effect of Discharge current (Ip) on the MRR,TWR,SR.

Discussions

1-Effect of pulse on time(Ton): From the figure(12) shown above we observe that, the increase in the pulse on time (Ton) leads to increases the number of pulses generated, which in turn increases the number of ions and electrons emitted from the surface of the metal and the tool. The kinetic energy of these ions and electrons that are converted to thermal energy increases the temperature of the surface metal and the tool, thus increase the melting point of the metal surface and the tool and the vaporization, which leads to increasing the rate of the metal removed and the rate of wear tool and the rate of roughness surface and from the figure(12) shown above we notice that the maximum rate of metal is removed at 200µs and then starts to decrease , the reason for this is when increase the values of the time of the pulse stops (Toff) that lead in turn to reduce the rate of metal removed(MRR). As for the rate of wear tool and the rate of roughness surface, it begins to decline after increasing the values of the time of stopping the flow of the pulse(Toff).

2-Effect of pulse off time (Toff): From the figure (13) shown above we observed that when the pulse off time(Toff) is increased, this reduces both the rate of the removed metal(MRR) and the wear rate of the tool(TWR). This is due to the increase of the pulse stopping time, this will reduce the size of the plasma channel due to the low number of ions and electrons emitted from the surface metal and the tool , thus reducing the melting point of the metal and the tool, it leads to reducing both the rate of the metal removed and the rate of wear tool. As for the rate of roughness surface, it is assumed that when the pulse of time(Toff) is increased, the surface roughness is reduced. However, from the figure(13) shown above we observe that there is an increase in surface roughness.

This is due to the combined effect of both pulse on time (Ton) and pulse current(Ip). In this case the effect of both pulse on time(Ton) and pulse current(Ip) is greater than the effect pulse of time(Toff).

3-Effect of pulse current(Ip): From the figure(14) shown above we observed that the increase in the current of the pulse(Ip) increases the rate of the removed metal and the rate of wear tool ,the rate of roughness surface. The reason is that when the pulse current is increased, it increases the number of pulses generated by increasing the transmission of ions and electrons between the surface metal and the tool .This leads to increase the size of the plasma channel formed between the surface of the work piece and the tool, which increases the temperature of the surface metal and the tool and the high melting point of each and thus increase the rate of metal removed and the rate of wear tool and also increase the roughness surface due to the increase in the number of pits on the surface of the metal. As shown in figure (14), there is an increase in both the rate of the removed metal and the roughness surface when the pulse current is increased. However, when we reach the value of 30A, we notice a decrease in both the rate of the removed metal and the roughness surface. The reason for this is to increase the pulse of time(Toff) values in this area, reducing the number of ions and electrons emitted from the surface of the metal and the tool. This will reduce the size of the plasma channel between the surface of the metal and the electrode, this causes the temperature of both the metal surface and the electrode to decrease, and so less of the rate of metal removed and the rate of the roughness surface

Conclusions

In this study, the effect of the current, the pulse on time and pulse off time were examined and their effect on both the rate of the removed metal and the rate of wear of the tool and the rate of surface roughness. A relationship was found by neural networks that linked the effect of each of the three variables above the rate of metal removed and the rate of wear of the tool, the roughness of the surface. This derived relationship can predict both the rate of the metal removed and the rate of wear of the tool and the rate of roughness of the surface if the increase or decrease of the current and the pulse on time and the pulse off time or any values are entered within the limits ,the relationship was derived on the valuable of the current and the the pulse on time and the pulse off time. And so we got the effect of this relationship combines three variables (Ip,Ton,Toff) combined.

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