

Modeling and Analysis of EDM Process parameters Using Taguchi Technique and Fuzzy Based Modeling

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Abstract

This paper deals with optimized model to investigate the effects of peak current, pulse on time, pulse off time and Tool lift time in Electrical Discharge Machining (EDM) process. Material Removal Rate(MRR) of titanium super alloy and Tool Wear Rate(TWR) utilizing copper as Tool electrode with positive polarity have been studied. Experiments were designed by Taguchi's technique and conducted by taking three levels of the peak current, pulse on time and pulse off time and tool lift time on Titanium super alloy. Fuzzy based model was developed to correlate the influences of the four independent variables and the response variables as MRR and TWR. The obtained results show that the peak current and Pulse ON time are the more influencing parameters on MRR and TWR. It is observed that the developed model is within the limits of 6% error when compared to experimental results. For required MRR and TWR the input parameters can be predicted from the established model.

Keywords: Titanium super alloy, Material removal rate, Tool wear rate, copper electrode, Design of Experiment, Fuzzy logic.

1. Introduction

Electrical discharge machining (EDM) is one of the most extensively used non-conventional machining process. It uses thermal energy to machine electrically conductive parts regardless of hardness of the material the distinctive advantage of EDM is in the manufacture of mould, die, automotive, aerospace and surgical components. EDM does not make direct contact between the electrode and the workpiece eliminating mechanical stresses, chatter and vibration during machining.

The traditional machining techniques are often incapable to machine the titanium alloys due to its high hardness and these can be machined economically by EDM and developed the optimized model to investigate the effects of peak current, pulse time and pulse off time on EDM performance characteristics of titanium alloy of Ti-6Al-4V utilizing copper electrode [Md. Ashikur et al., 2010]

Srinivasa Rao et al, [3] developed the fuzzy logic based model for predicting die sinking ED machining of AISI 64430 (HE30) Aluminum alloys characteristics such as metal removal rate (MRR). The tool wear rate (TWR) and surface roughness. Lokeshwar Rao et al, [4] described the optimum cutting parameters for Titanium alloy (Ti-6Al-4V) using wire cut. Electrical discharge machining process (WEDM) using Taguchi's L_{25} orthogonal array under different conditions and developed the regression model for MRR & Ra. Oguzhan Yibmaz et al, [5] have done considerable number of experiments on Aisi 4340 tool steel to investigate the relationships and effects of EDM machining parameters between each others and developed the fuzzy based model to study effect of discharge current pulse on time pulse off time on erosion rate and percentage electrode wear rate.

Yih-fong Tzeng et. Al., [6] described the application of the fuzzy logic analysis coupled with taguchi methods to optimize the precision and accuracy of the high speed electrical discharge machining process. Krishna Mohan Rao et.al, [7] done the experiments on maraging steel metal with copper using EDM taguchi orthogonal array had been used and conducted 27 experiment for the three trials and studies the effect of current, pulse on time and duty factor on MRR and surface roughness and concluded that MRR and surface roughness increases with increase in current and duty factor but as pulse on time increases MRR & Surface roughness decreases. Lin C.L., Lin J.L and Ko T.C. et.al., [8] have studied the EDM process parameters and developed gray relational model and fuzzy based taguchi method for optimizing the multi responses of process. L_9 orthogonal array SK D11 alloy steels and concluded that both approaches can generally improve process responses such as electrode wear ratio, metal removal rate and surface roughness. Kibria, G, and Saker B.R. [9] studied the effect of different dielectrics such as Kerosene, deionized water, boron carbide (B_4C) powder suspended Kerosene and deionized water on the performance measures such as MRR, TWR, overcut and diameter variance and surface integrity during machining of Titanium ally (Ti-6Al-4V) and concluded that MRR is high with deionized water dielectric compared to pure kerosene. TWR is also more when B_4C -mixed. Deionized water is used compared to pure kerosene.

El-Taweel T.A. et.al., [10] studied the effect of the input machining parameters such as TiC (wt%), peak current, flushing pressure and pulse on time on the machining performance such as MRR and TWR the experiments were carried out CK45 steel using Die sink EDM and concluded that peak current was the most effecting parameter on both MRR and TWR. Swarup. S. Mahapatra and Amar Patnaik et. al., [11] investigated the influence of inputs parameters on responses MRR & TWR and the experiments were designed to conduct the experiments based on L_{27} . Orthogonal array from the table given by the Taguchi. Biswas and Shailesh Dewangan et. al., [12]

presented the use of the fuzzy logic coupled with taguchi method for optionization of EDM process with multiple performance characteristics. Machining has been carried out on the A1S1p20 steel work piece material using cylindrical copper electrode and studied the influence of pulse current, pulse duration, work time, lift time and inter electrode gap on MRR and surface roughness. The experiments carried out using L₂₇ orthogonal array

2. Experimental Details

Experiments were carried out on die sinking EDM of type Askar microns model V3525 with servo head constant gap voltage positive polarity. Commercial 30 Grade EDM Oil was used as Dielectric fluid. The investigation was done on Titanium super alloys with hardness 90 HRC. The chemical composition of work material is given in table.1 the size of work pieces are 40mmX30mmX6mm and the copper electrode of 12mm diameter was used for the experimentation because of higher MMR and lower TWR¹². In the present investigation the effect of the four process parameters had been studied, those are the Pulse Current(I_p), Pulse ON time(T_{on}), Pulse OFF time(T_{off}) and Tool LIFT time(T_{lift}).Machining is carried out for 10 minutes for all the experiments and MRR and TWR are calculated for one minute for each experiment. The MRR and TWR are calculated by measuring the weight difference of work piece and electrode before and after machining using a digital weighing balance of type AY220 with precision 0.001gm. The MRR and TWR are calculated by the formula given below.

$$MRR = \frac{(wp1-wp2)}{T} \text{ mg/minute}$$

Where wp1 and wp2 are the weights of the workpiece before and after machining, T is the machining time.

$$TWR = \frac{(wt1-wt2)}{T} \frac{mg}{minute}$$

Where wt₁ and wt₂ are the weights of the workpiece before and after machining, T is the machining time.

Workpiece and the tool materials are Titanium super alloy and copper(99.9% of Cu) respectively. The coposition of the workpiece is given in table.1. The results of MRR and TWR are given in table.3.

Table 1: Chemical composition of work material.

Titanium	Al	C	Mo	Zr	Si	Fe	P	V
Base	6%	0.13%	1.25%	2%	0.15%	0.3%	1.7%	0.3%

The process parameters are selected based on the preliminary experiments and machine operating conditions. Taguchi method is one of the most efficient tools for the analysis of manufacturing design. The design of experiments is based on Taguchi's L₂₇ orthogonal array was taken for conducting the experiments. The levels of the process parameters are given in table.2. and the results of MRR and TWR got from experiments are given in table.3. along with the modeling results and also % of error in modeling.

Table 2: Process parameters and their levels.

Parameters	Level 1	Level 2	Level 3
Current(Amp)	9	12	15
Pulse ON time(μ s)	5	20	50
Pulse ON time(μ s)	20	50	100
Tool LIFT time(μ s)	5	10	20

Table 3: Results of MRR and TWR Actual and modeling.

S. No	Current In (amp)	T _{on} (μ s)	T _{off} (μ s)	T _{lift} (μ s)	MRR (Actual)	MRR (Model) mg/Modeling) mg/min	% of Error in MRR	TWR (Actual) mg/min	TWR (Model) Modeling) mg/min	% of Error In TWR
1	9	5	20	5	9	9.07	-0.78	1.5	1.5	0
2	9	5	50	10	4.9	4.87	0.61	0.6	0.593	1.16
3	9	5	100	20	1.5	1.6	2.4	0.6	0.593	0.16
4	9	20	20	10	12.4	12.1	2.4	0.3	0.304	-1.3
5	9	20	50	20	8.6	9.07	-5.46	0.2	0.202	-1
6	9	20	100	5	5.3	5.26	0.7	0.267	0.264	0.37
7	9	50	20	20	10.1	10.1	0	0.233	0.234	0
8	9	50	50	5	13.2	13.7	-3.78	0.5	0.508	-1.6
9	9	50	100	10	7.7	7.34	4.6	0.2	0.202	-1
10	12	5	20	10	9.13	9.07	0.66	0.9	0.916	-1.7
11	12	5	50	20	3.867	3.86	0.18	0.3	0.304	-1.3
12	12	5	100	5	3.44	3.43	0.29	1.23	1.24	-0.8
13	12	20	20	20	7.3	7.34	-0.55	0.73	0.73	0
14	12	20	50	5	12.8	12.4	3.125	0.2	0.202	-1
15	12	20	100	10	6.1	6.07	0.49	0.3	0.304	-1.5
16	12	50	20	5	12.7	12.4	2.3	0.4	0.406	-1.3
17	12	50	50	10	10.8	10.7	0.9	0.3	0.304	0
18	12	50	100	20	5.2	5.26	-1.15	0.1	0.1	-1.87
19	15	5	20	20	8.6	9.07	-5.46	1.07	1.07	-3.3
20	15	5	50	5	10.7	10.7	0	1.2	1.24	-3.3
21	15	5	100	10	4.9	4.87	0.61	0.9	0.916	-1.7
22	15	20	20	5	24.3	24.3	0	3.3	3.3	0
23	15	20	50	10	17.4	17.3	0.57	2.2	2.07	5.9
24	15	20	100	20	7.7	7.34	4.67	0.7	0.712	-1.7
25	15	50	20	10	11.13	1.7	3.86	0.733	0.73	0.4
26	15	50	50	20	8.166	8.2	0.41	0.13	0.134	-3.07
27	15	50	100	5	14.4	13.7	4.86	1.1	1.10	0

3. Fuzzy Logic Modeling

Fuzzy based system consist of the various steps such as Data definition, fuzzification of inputs, implication, agrigation and defuzzification. They are described briefly as follows.

3.1. Data Definition

The designer has to determine which process attributes should be taken as inputs and outputs to the model. In the present study Current Pulse on time, Pulse off time and tool lift time have been taken as input parameters and MRR and TWR as the output parameters.

3.2. Fuzzification of inputs

The fuzzification process maps input numbers into corresponding fuzzy memberships. This is required in order to activate rules that are in terms of linguistic variables. The fuzzifier takes input values and determines the degree to which they belong to each of the fuzzy sets via membership functions. It is to be noted that, so far there is no standard for choosing the proper shape of Fuzzy membership functions. Hence trial-and-error methods are usually exercised. The most widely used membership functions are triangular, trapezoidal and arcs. In the present study, triangular membership functions are chosen. The relationship between inputs and outputs in a fuzzy system is characterized by linguistic statements which are called fuzzy rules they are defined based on experimental work, expert and engineering knowledge. The number of fuzzy rules in a fuzzy system is related to the number of fuzzy sets for each input variable. In the present study there are three inputs they are Current (3 states), Pulse on time (3 states), Pulse off time (3 states) and Tool lift time (3 states). Therefore the maximum numbers of rules for this system can be 81. The set of fuzzy rules extracted from the experimental data. The Fuzzy member functions for Input variables are shown in Fig.3.1. and member fuctions for MRR are shown in fig.3.2. similarly triangular fuctions are used as the member fuctions for TWR, not shown here.

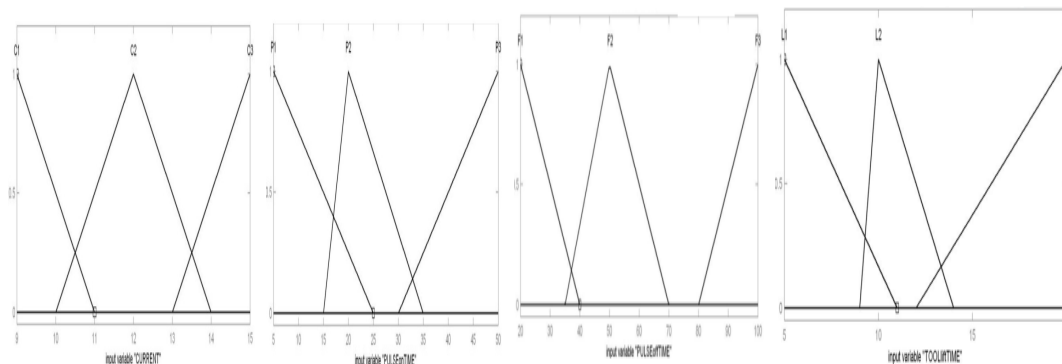


Fig. 3.1: Fuzzy member functions for Input variables.

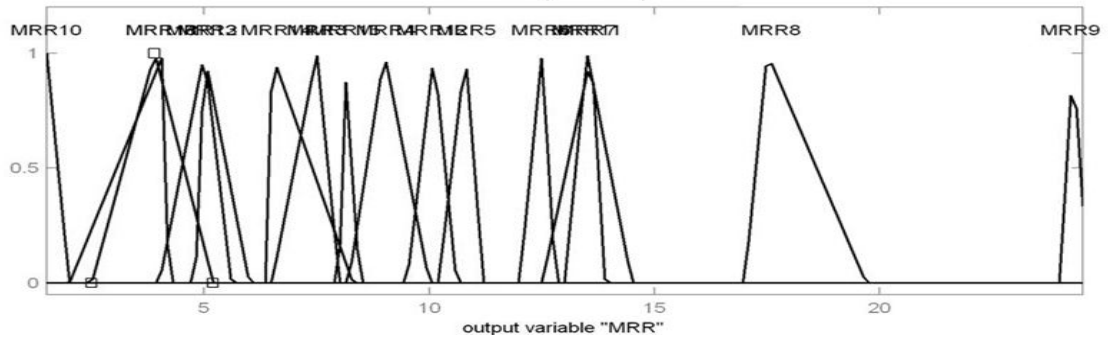


Fig. 3.2: Output member functions for MRR.

3.3. Implication

The implication is used for shaping the consequent (the final or the than part of a fuzzy rule), based on the antecedent (The initial or the if it of the fuzzy rule .The input to the implication process is a single number given by the antecedent, and the output is a fuzzy set. Two commonly used method of implication are the minimum and the product. Illustration of Implication diagram is shown in fig.3.3.

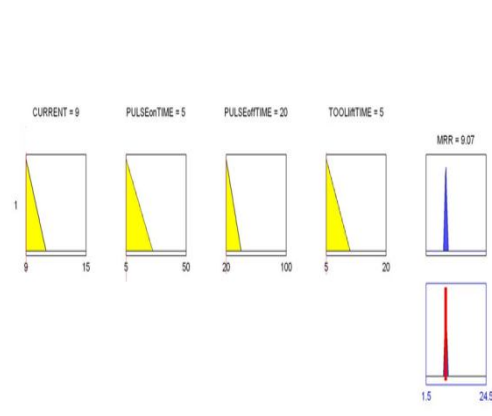


Fig. 3.3: Implication Diagram for MRR.

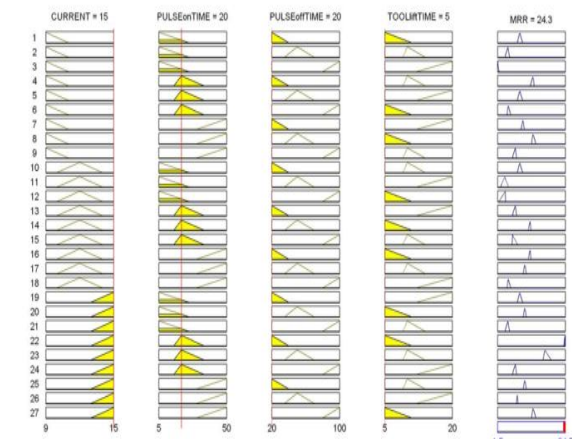


Fig. 3.4: Illustration of Aggregation method for MRR.

3.4. Aggregation

The process of combining output fuzzy sets in to a single set is called aggregation, a process that unifies the output of all the rules. The inputs to the aggregation process are truncated or modified output fuzzy sets obtained as the output of the implication process. The output of aggregation process is single output fuzzy set that represents the output variable. Aggregation occurs only once for each output variable. Since the aggregation method is commutative the order in which the rules are executed is not important. The commonly used aggregation method is maximum method. Illustration of Aggregation method for MRR is shown in fig.3.4.

3.5 Defuzzification

In order to obtain a crisp output, we need a defuzzification process. The input to the defuzzification process is a fuzzy set (the aggregated output fuzzy set) and the output of the defuzzification process is a single number. Many defuzzification techniques have been proposed in the literature, The most commonly used are Centroid and Bisector methods. The fuzzy model developed is consistent with the experimental observations.

3. Conclusion

Fuzzy model was developed based on Experimental results obtained from the DOE. Fuzzy model selects more precise selection of EDM process parameters the system is easy to use ,provide compact selection and enables the un skilled user to select the necessary process parameters which leads better MRR and TWR. The close correlation is observed between experimental output and fuzzy model output. The fuzzy model predicts MRR and TWR within 5.4% and 5.9% error respectively and also observed that Current and Pulse on time are more influencing parameters on MRR and TWR.

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