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Predicting Material Removal Rate of EDM of 95WC/5NI Composites Using Fuzzy Logic

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***Abstract*— In this study, the material remove rate, obtained when machining electric-discharge (EDM) of 95WC/5ni Composites, were modelled using fuzzy logic. Input variables consisted of rotational speed, current, pressure and pulse on time while output variable was material remove rate (MRR). Fuzzy logic was developed using Matlab 2013. The mean absolute errors (MAE) of the predicted values was employed to compare the results with the previously published results obtained using response surface method. The results showed that the predictive model using fuzzy logic model has reduced the errors by 0.017, which means, using fuzzy logic model to predicate the material remove rate is sufficiently accurate.**

Keywords*— Electrical Discharge Machining (EDM), prediction, material remove rate, fuzzy logic model.

I. INTRODUCTION

Electrical Discharge Machining EDM is a unconventional manufacturing process based on removal of material from a part by means of a series of repeated electrical sparks created by electric pulse generators at short intervals between an electrode tool and the part to be machined immersed in dielectric fluid. At present, EDM is a widespread technique used in industry for high precision machining of all types of conductive materials such as metallic alloys, metals, graphite, composite materials or some ceramic materials[1]. Since there is no contact between the tool and work piece in EDM, machining problems like mechanical stresses, chattering and vibrations does not arise during machining. In spite of advantages of EDM, there are disadvantages like low material removal rate and poor surface finish which restricts its application in industries to some extent[2].

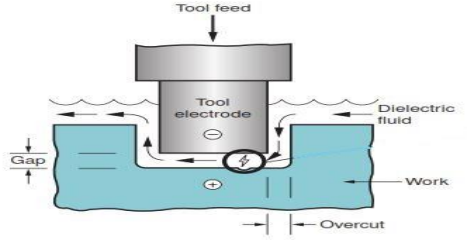

Fig.1 Electric discharge machining (EDM) [7]

The prediction of optimal machining conditions for higher the material remove rate (MRR) plays a very important role in process planning, there was a study that was investigated the machining parameters (pulse current, pulse ON time and pulse off time) on the response material remove rate (MRR) during EDM process of aluminum silicon carbide composite[3]. The predicted electrical discharge machining of AISI 64430 (HE30) aluminum alloy characteristics such as the metal removal rate) MRR), the tool wear rate (TWR), the surface roughness (Ra value) and the hardness (HRB) using fuzzy mathematical method was studied[4]. The process parameters taken into consideration were the current (I), the open-circuit voltage(V), the servo (SV) and the duty cycle (η) [4]. It was also demonstrated that the integrated multiple responses optimization of the electrical discharge machining EDM considering Fuzzy logic and the Taguchi method[5]. The work piece material was AISI P20 toll steel and a cylindrical copper electrode was used with side impulse flushing. The discharge current, pulse on time, work time, lift time, and anti-arc sensitivity (ASEN) were the control parameters of EDM[5].

The objectives of this paper are stated as follows:

1. To predict material remove rate (MRR) using Fuzzy logic, as a function of four different parameters, power supply voltage, pulse-on time, peak current and interval time.
2. To compare results with a previous published work[6].

II. EXPERIMENTAL DETAILS

A. Material

95WC/5ni Composites was the target material used in this experiments. For each experiment, a new set of tool and work piece have been used.

B. Experimental Design

The number of experiments shown table 1 was obtained from previous published work[6]. As there are four input parameters namely rotational speed, current, pressure and pulse on time therefore total of 30 experiments were carried out. The output response selected for this study is Material Removal Rate (MRR). The MRR has been calculated using the following expression:

$$MRR = \frac{\text{Volume of metal removed from part}}{\text{Time of machining}} \quad (1)$$

TABLE 1. THE DESIGNED EXPERIMENTAL DATA OF CUTTING (EDM) OF 95WC/5NI COMPOSITES

No.	Rotational speed, S (rem)	Current, A (C)	Pulse on time, µs (T)	Pressure ,kg/cm^2 (P)	MRR (mg/ min)
1	300	15	500	1.25	3.36
2	500	15	500	1.25	6.03
3	300	25	500	1.25	9.36
4	500	25	500	1.25	9.03
5	300	15	700	1.25	4.36
6	500	15	700	1.25	3.03
7	300	25	700	1.25	8.36
8	500	25	700	1.25	11.03
9	300	15	500	1.75	15.91
10	500	15	500	1.75	14.58
11	300	25	500	1.75	13.91
12	500	25	500	1.75	12.58
13	300	15	700	1.75	14.91
14	500	15	700	1.75	13.58
15	300	25	700	1.75	15.91
16	500	25	700	1.75	14.58
17	200	20	600	1.5	9.1
18	600	20	600	1.5	7.65
19	400	10	600	1.5	2.65
20	400	30	600	1.5	9.65
21	400	20	400	1.5	9.25
22	400	20	800	1.5	8.25
23	400	20	600	1	7.31
24	400	20	600	2	18.51
25	400	20	600	1.5	6.65
26	400	20	600	1.5	6.85
27	400	20	600	1.5	7.12
28	400	20	600	1.5	8.43
29	400	20	600	1.5	9.75
30	400	20	600	1.5	7.12

The upper (+2) and lower (-2) levels of all the four parameters and their designations are shown in table 2.

TABLE 2. FACTORS AND THEIR LEVELS

No.	*Parameters*	*Unit*	*Notation*	*Level*				
				-2	-1	0	1	2
1	Rotational speed	rpm	S	200	300	400	500	600
2	Current	A	C	10	15	20	25	30
3	Pulse-on time	µs	T	400	500	600	700	800
4	Pressure	kg/cm^2	P	1	1.15	1.5	1.75	2

III. DEVELOPMENT OF THE MODEL

Fuzzy logic is a highly flexible and non linear modelling technique with an ability to learn the relationship between inputs variables and output features [8]. The most successful applications of fuzzy set theory is observed in modelling the experimental data involving certain uncertainties between the relationships of input process variables and responses[8]/[9]. Its major features are the use of linguistic variables rather than numerical variables. Linguistic variables are defined as the variables whose values are sentences in natural language (such as low, medium and high) and can be represented by fuzzy sets. Fuzzy sets are characterized by fuzzification, membership functions, a fuzzy rule, an inference system and a defuzzification inference. The structure of foure inputs, and output fuzzy logic controller developed for this present research is shown in Figure 2. The inputs values to the model were given in linguistic form and after fuzzification, the outputs was obtained in crisp form.
The fuzzy rules are expressed in the form of fuzzy conditional statements Ri of the type Ri: if x is small y is large THEN z is large Where x and y are fuzzy variables, and small and large are labels of fuzzy set. If there are i= 1 to n rules, the rule set is represented by union of these rules, R= R1 else R2 else .....R

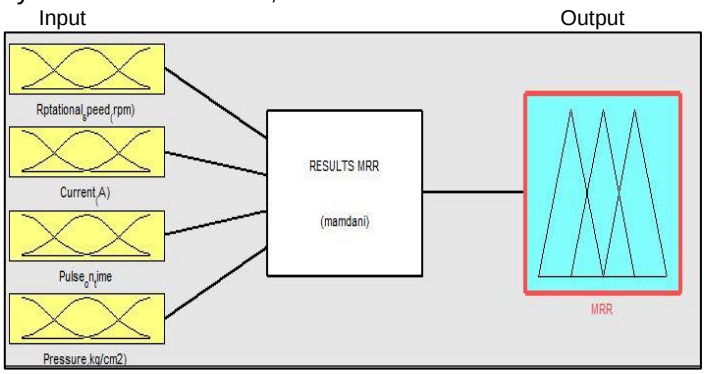

Fig. 2. Input-Output Parameters of Fuzzy Logic Control Model

A fuzzy logic controller is based on a collection of control rules. The execution of these rules is governed by the compositional rule. In this study the triangular membership functions were used for the input process parameters such as rotational speed, current, pressure and pulse on time to predict the material removal rate in EDM of 95WC/5ni composites.The membership function for each inputs variables were divided into five levels (very low, low, medium, high and very high) and output variable was divided into seven levels (very very low,very low, low, medium, high and very high,very very high). The fuzzy logic controller was Mamdani type and contained a rule base. This base comprised of groups of rules and each output was defined by thirty rules. The rules based on knowledge to predict the material removal rate in EDM of 95WC/5ni Composites is given in table 3.

TABLE 3. FUZZY RULE FOR EDM OF 95WC/5NI COMPOSITES

1. IF Rotational speed is Low AND Current is Low AND Pulse on time is Low and Pressure is Low THEN Material removal rate is Very Very Low
2. If Rotational speed is High AND Current is Low AND Pulse on time is Low AND Pressure is Low THEN Material removal rate is Very Low
3. IF Rotational speed is Low AND Current is High AND Pulse on time is Low AND Pressure is Low THEN Material removal rate is Medium

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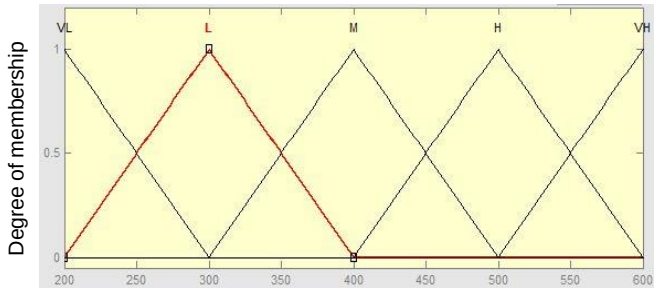
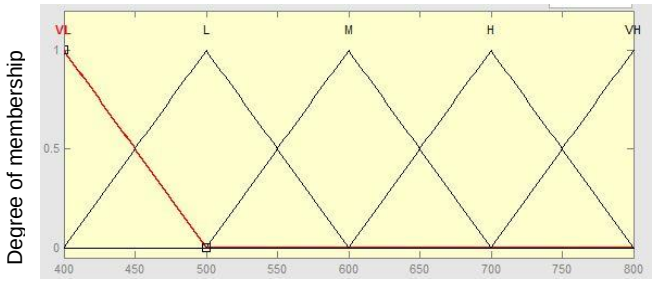
29. IF Rotational speed is Medium AND Current is Medium AND Pulse on time is Medium AND Pressure is Medium THEN Material removal rate is Medium
30. IF Rotational speed is Medium AND Current is Medium AND Pulse on time is Medium and Pressure is Medium THEN Material removal rate is Very Low

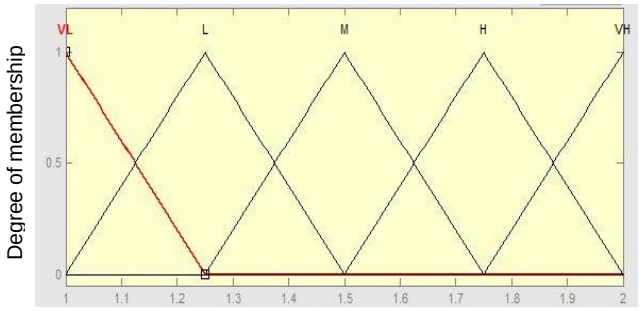
The fuzzy inputs are linguistically divided into five levels such as very low (L), low (L), medium (M), high (H) and very high (VH) which shown in Figure 3. Figure 4 shows the fuzzy output linguistically divided into seven levels such as very very low (VVL), very low (L), low (L), medium (M), high (H), very high (VH) and very very high (VVH).



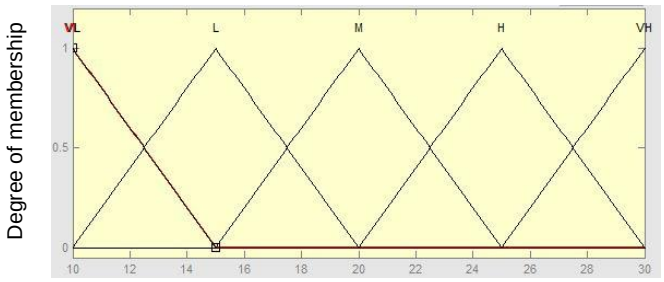
(a) Rotational speed, rpm



(c) Pulse-on time,μs

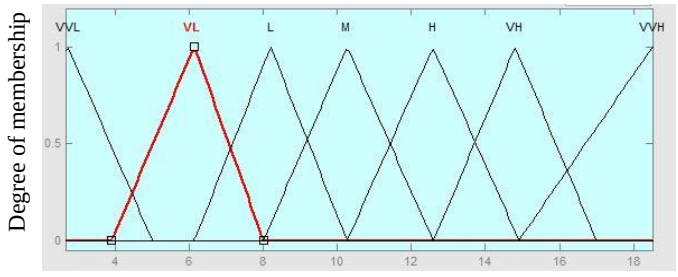


(d) Pressure, kg/cm2



(b) Current, A

Fig. 3. Membership functions for inputs process parameters: (a) Rotational speed, S; (b) Current, A (c) Pulse-on time; (c) & (d) Pressure, kg/cm2 of 95WC/5ni Composites



Material Removal Rate (MRR)

Fig.4. Membership functions for outputs: material remove rate (MRR)

IV. SIMULATION OF FUZZY LOGIC MODEL

In this study, the fuzzy model has been developed based on 30 experiments of EDM of 95WC/5ni Composites process parameters. The fuzzy model was simulated for test cases which has been done within the range of the fuzzy set. The experiments was conducted for the five levels of each process parameters. The purpose of the simulation was to minimize the error of outputs for test case experiments. A MATLAB Simulink model was developed to predict material removal rate of the EDM

of 95WC/5ni Composites process. Moreover, to confirm the adequacy of fuzzy logic model, the predicted values of the material removal rate predicted by using the proposed fuzzy model were compared with the previously published predicted values of the material removal rate of the EDM of 95WC/5ni Composites process by using RSM, these comparison is shown in Table 4 with their mean absolute error MAE. The MAE for the predicted of material removal rate by using the proposed fuzzy logic model is lower than the predicted of material removal rate by using RSM, the difference was observed to be 0.017.

TABLE 4. THE EXPERIMENTAL, PREDICTED AND MEAN ABSOLUTE ERROR OF THE MATERIAL REMOVAL RATE OF THE 95WC/5NI COMPOSITES FOR TEST CASES

No.	*Experimental MRR, (mg/min)*	*Predicted MRR, Using RSM, (mg/min)*	*Predicted MRR, Using Fuzzy, (mg/min)*	*Error Using RSM*	*Error Using Fuzzy*
1	3.36	4.2346	3.39	0.8746	0.03
2	6.03	4.9812	6.01	1.0488	0.02
3	9.36	8.6096	10.3	0.7504	0.94
4	9.03	9.6062	10.3	0.5762	1.27
5	4.36	2.7762	3.39	1.5838	0.97
6	3.03	3.2729	3.39	0.2429	0.36
7	8.36	9.4012	8.19	1.0412	0.17
8	11.03	10.1479	12.6	0.8821	1.57
9	15.91	14.8429	14.8	1.0671	1.11
10	14.58	13.3396	14.8	1.2404	0.22
11	13.91	13.4679	12.6	0.4421	1.31
12	12.58	12.2146	12.6	0.3654	0.02
13	14.91	14.1346	14.8	0.7754	0.11
14	13.58	12.3812	12.6	1.1988	0.98
15	15.91	15.0096	14.8	0.9004	1.11
16	14.58	13.5063	14.8	1.0737	0.22
17	9.1	9.8275	10.3	0.7275	1.2
18	7.65	9.0708	8.19	1.4208	0.54
19	2.65	4.4742	3.39	1.8242	0.74
20	9.65	9.9742	10.3	0.3242	0.65
21	9.25	9.9075	8.26	0.6575	0.99
22	8.25	9.7408	8.19	1.4908	0.06
23	7.31	7.0008	10.6	0.3092	3.29
24	18.51	20.9675	14.8	2.4575	3.71
25	6.65	7.6533	8.24	1.0033	1.59
26	6.85	7.6533	8.24	0.8033	1.39
27	7.12	7.6533	8.24	0.5333	1.12
28	8.43	7.6533	8.24	0.7767	0.19
29	9.75	7.6533	8.24	2.0967	1.51
30	7.12	7.6533	8.24	0.5333	1.12
			MAE	**0.9673**	**0.9503**

V. CONCLUSIONS

In this paper an attempt was made to predict the material removal rate in EDM of 95WC/5ni Composites as affected by the rotational speed, current, pressure and pulse on time. The fuzzy clustering technique used was found to be adequate for establishing the relationship between the input process parameters and the outputs. The developed fuzzy logic model was also tested by comparing the results with a previously published results using RSM technique. The comparison was carried out based on the mean absolute error between the predicted values and the experimental values shown in Figure 5. The fuzzy model gave lower mean absolute error.

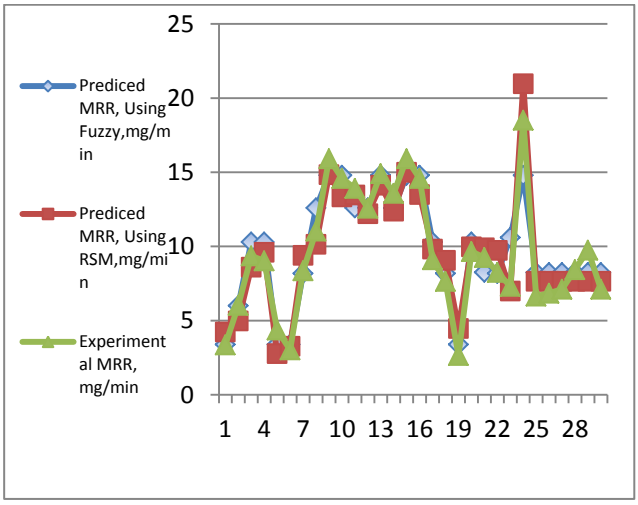


Fig.5. Comparison of results between, Predicted MRR using RSM and Predicted using Fuzzy logic

REFERENCE

[1] Vishwakarma M., Khare v. K., Parashar v. 2012. "Response surface approach for optimization of Sinker Electric Discharge Machine process parameters on AISI 4140 alloy steel", International Journal of Engineering Research and Applications, Vol. 2, pp 185-189.

[2] Bikramjit S., Chandan D. S., Jaswinder S. 2015. "Optimization of Chromium Mixed Powder EDM parameters using Response Surface Methodology for H13 Tool steel Machining", International Journal of Multidisciplinary and Scientific Emerging Research, Vol.4, No.2, pp 1068-1079.

[3] Pradeep K. J., Giriprasad C. R. 2013. "Investigation on Application of Fuzzy logic Concept for Evaluation of Electric Discharge Machining Characteristics While Machining Aluminium Silicon Carbide Composite", International Journal of Science, Engineering and Technology Research, Vol. 2, pp 1804-1809.

[4] P. Rao S., Prasad K., Reddy B. 2011. "Fuzzy Modeling for Electrical Discharge Machining of Aluminum Alloy", www.arpapress.com, Vol. l9, pp 112-120.

[5] Biswas C. K., Shailesh D. 2012. "Optimisation of EDM Process with Fuzzy Logic Technique", International Conference on Metallurgical, Manufacturing and Mechanical Engineering, pp 346-347.

[6] Chandrasekaran V., Kanagarajan D., Karthikeyan R. 2013." Optimization of EDM characteristics of wc/5ni composites using response surface methodology", International Journal of Recent Technology and Engineering, Vol.2, pp 108-115.

[7] Groover M. 2010. " Processes Fundamentals of Modern Manufacturing",4th, John Wiley & Sons, Inc.

[8] Elmabrouk O. 2014. "Predicting Surface Roughness of WEDC OF SICP/6061 AL MMC Process using fuzzy logic", International Conference on Manufacturing Research, pp 169-174.

[9] Bandler W., Kohout L. J., 1988. "Special properties, closures and interiors of crisp and fuzzy relations", Fuzzy sets and Systems, Vol. 26, No. 3, pp. 317-332.

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