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Fuzzy Modeling to Specify Various Machining Parameters in Electrical Discharge Machining (EDM) of INCONEL625 Using Copper Electrode

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Abstract

Condition monitoring of the machining process is very important in today's precision manufacturing, especially in the electrical discharge machining (EDM). This paper shows a fuzzy-based algorithm for prediction of material removal rate (MRR) and tool wear ratio (TWR) in the electrical discharge machining (EDM) processes. In this system peak current (I_p), voltage (V) and duty cycle (D) are the input parameters and output parameters are MRR and TWR. The proposed fuzzy model in this study provides a more precise and easy selection of EDM input parameters, respectively for the required MRR and TWR which leads to better machining conditions and decreases the machining costs. The fuzzy modeling of EDM was able to predict the experimental results with very high accuracies.

Keywords: *Fuzzy modeling, EDM, MRR, TWR*

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INTRODUCTION

Electrical discharge machining (EDM) is widely accepted manufacturing process for the machining of materials like super alloys which is not possible to machine by conventional manufacturing processes. INCONEL625 is the hard material which is widely used in marine, aerospace industry, chemical processing, nuclear reactor, pollution control equipment. To remove the difficulties in machining of INCONEL625, EDM has been a suitable process. Selection of EDM parameters is vague and generally based on heuristics which is difficult to model and is based on the specialty them of person [1].

FUZZY LOGIC

Fuzzy logic has a history in philosophy and mathematics. Fuzzy logic is a form of mathematical logic in which truth can be assumed between value zero and one. Fuzzy logic designed for situations where information is in exact and traditional on/off are not possible [2]. It divides data into vague categories like hot, medium and cold. Fuzzy logic provides simple way of arriving at definite conclusion based upon the emprise and noise. Fuzzy logic uses semantic terms to develop the relationship between input and output variables. Here the fuzzy model has been designed for selecting better EDM parameters. Fuzzification, membership function and defuzzification are main stages for the development of fuzzy model [2].

Membership Function (MF)

A membership function is a shape of the profile that shows how points in the input are mapped into membership degree of membership between 0 and 1. There are a number of methods for representing the membership function that show fuzziness. Because of the importance of the shape of the membership function; a more attention has been focused on development of the membership functions [2]. There are some types of membership function shapes like triangular, trapezoidal, bell curves and sigmoid.

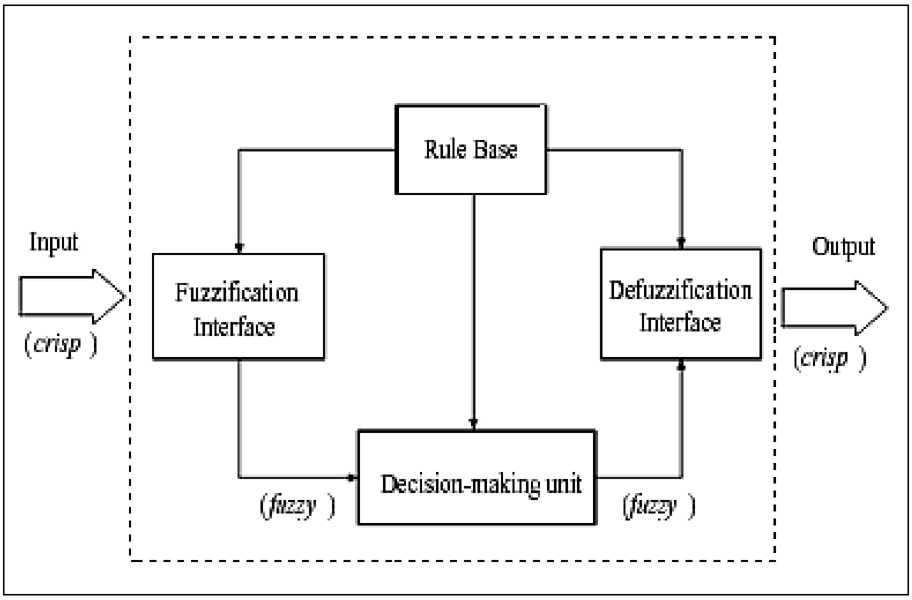

Fig. 1: *Basic Configuration of a Fuzzy Logic System.*

Fuzzification

Fuzzyfication is the process of transforming crisp input value into linguistic values. There are various steps of fuzzification. In first step, input parameter values are translated into linguistic concepts which are related by fuzzy set. In second step membership functions are applied to the measurement and degree of membership is determined [3].

Defuzzification

Defuzzification is the process of converting fuzzy set value into crisp value. The various methods of defuzzification are; maximum membership method, centroid method and weight average method. Centric of the area is the most widely used defuzzification method which is of the calculation of expected values of probability distributions [4].

EXPEIMENT SETUP

The experiments were performed to find the effects between input machining parameters (peak current, voltage and duty cycle) on the output machining parameters like material removal rate (MRR) and tool wear ratio (TWR) in electrical discharge machining (EDM) processes. Experiment was carried out on electrical discharge machining Joe mars AZ50. The material used for work piece is INCONEL625 which is nickel chromium super alloy.

The electrode material is copper. Peak current (I_p), voltage (V) and duty cycle (D) were selected as input parameters during machining process [5]. The mass of work piece and electrode before and after measuring with the help of weight measuring instrument with. Material removal rate (MRR) and tool wear rate (TWR) were the output parameters. The schematic diagram of experimental set-up has been shown in Figure 2.

Table 1: *Work Piece Material and Properties.*

Property	Unit	Value
Density	g/cm3	8.44
Melting point range	C	1290–1350
Ultimate tensile strength	MPa	827–1103
Hardness	HRC	175–240
Yield strength	MPa	414–758
Thermal conductivity	W/m K	11.4

Table 2: *Experimental Condition and Process Variables.*

Tool diameter	10 mm
Tool polarity	Positive
Dielectric	Kerosene
Work piece shape	10*10*5 (mm)
Peak current	4, 13, 21 amp
Voltage	160, 180, 200 V
Duty cycle	0.278, 0.477, 0.680

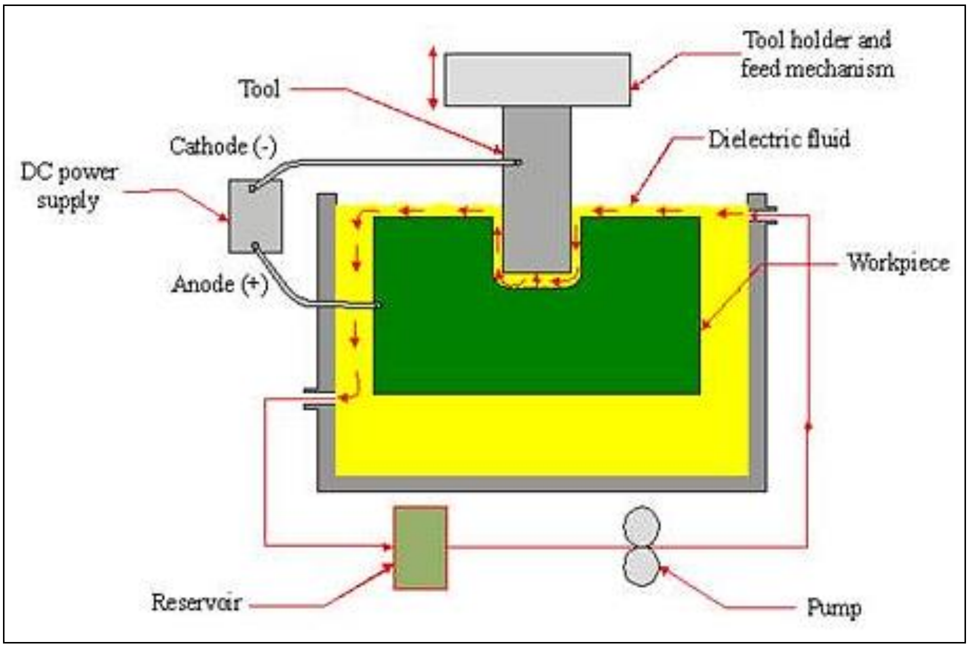

Fig. 2: *Schematic Diagram of the EDM Process.*

Fig. 3: *Joemars AZ50.*

FACTORIAL DESIGN AND FUZZY EXPRESSION

Design of experiments (DOE) is an important tool for analysis of affect of input machining parameters on the output machining parameter. The prediction of EDM process is based on the input machining parameters by full-factorial design methods. Full-factorial method was used in the experiment in this paper. The full factorial design was determined on peak current, voltage and duty cycle duration in input machining parameters. Each input machining parameter consisted of three levels. So there were three input machining parameters and three levels. So the numbers of experiments carried out were 3*3*3=27. Table 3 gives the results of the experiments. By using of trial and error method, it can be concluded that the triangular membership functions give better results. The number of fuzzy sets for peak current (I_p), voltage (V), duty cycle (D), material removal rate (MRR) and tool wear ratio (TWR) in EDM process. Total number of fuzzy rules used for these experiments are 27.

Table 3: *Experimental Result of EDM.*

Sr No.	Peak Current (Ip) (amp)	Voltage (V)	Duty Cycle	MRR (gm/min)	TWR (WRR/TWR)
1	4	160	0.278	0.007	0.029
2	4	180	0.278	0.0086	0.024
3	4	200	0.278	0.0081	0.018
4	13	160	0.278	0.0134	0.011
5	13	180	0.278	0.014	0.015
6	13	200	0.278	0.0143	0.015
7	21	160	0.278	0.0131	0.008
8	21	180	0.278	0.0175	0.030
9	21	200	0.278	0.0142	0.008
10	4	160	0.477	0.0845	0.023
11	4	180	0.477	0.1155	0.017
12	4	200	0.477	0.114	0.016
13	13	160	0.477	0.12	0.019
14	13	180	0.477	0.1189	0.008
15	13	200	0.477	0.1467	0.015
16	21	160	0.477	0.1163	0.021
17	21	180	0.477	0.1108	0.018
18	21	200	0.477	0.263	0.010
19	4	160	0.680	0.1079	0.028
20	4	180	0.680	0.2182	0.018
21	4	200	0.680	0.2696	0.011
22	13	160	0.680	0.2102	0.029
23	13	180	0.680	0.2527	0.014
24	13	200	0.680	0.1822	0.013
25	21	160	0.680	0.2157	0.027
26	21	180	0.680	0.28	0.007
27	21	200	0.680	0.2778	0.007

DISCUSSION

The result obtained throughout the experimental analysis of material removal rate (MRR) and tool wear ratio (TWR) after period of machining process compared with the result obtained by the fuzzy modeling is discussed below:

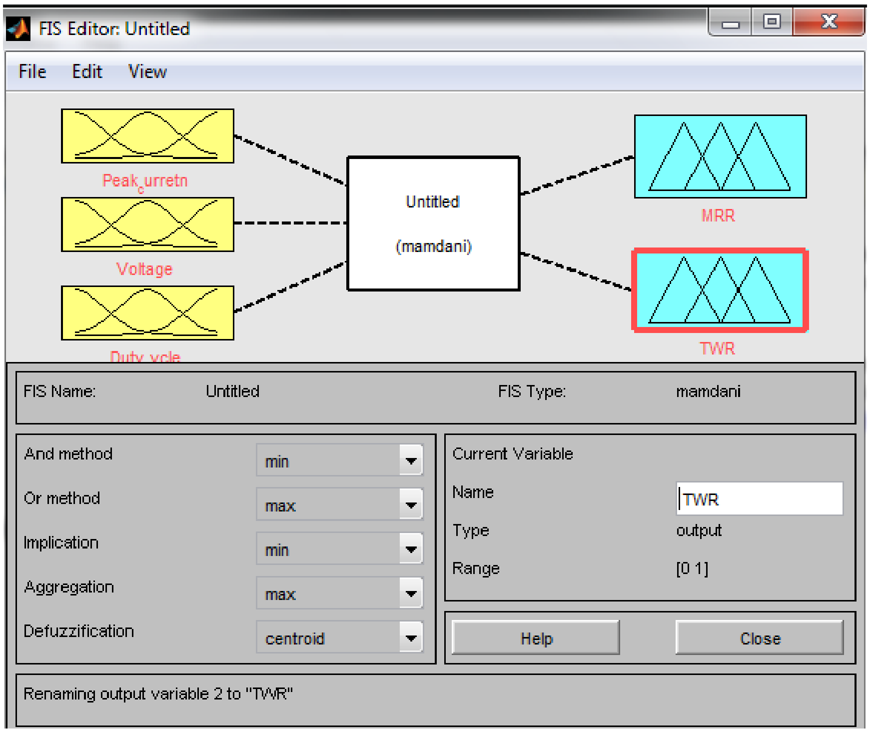

Fig. 4: *Fuzzy Logic Parameters.*

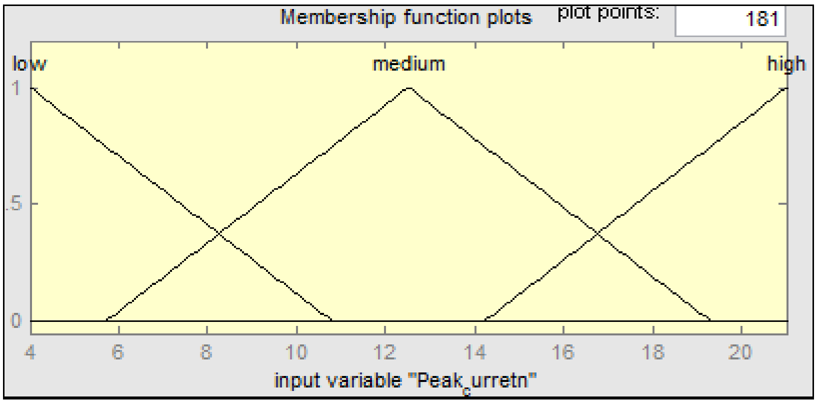

Fig. 5: *Plot Degree of Membership Function for Peak Current.*

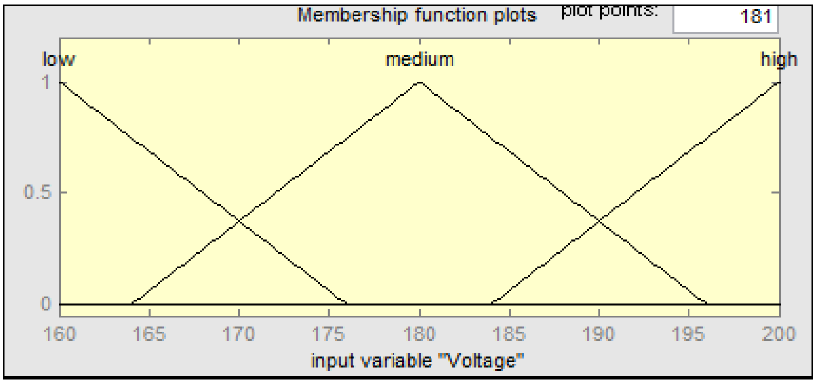

Fig. 6: *Plot Degree of Membership Function for Voltage.*

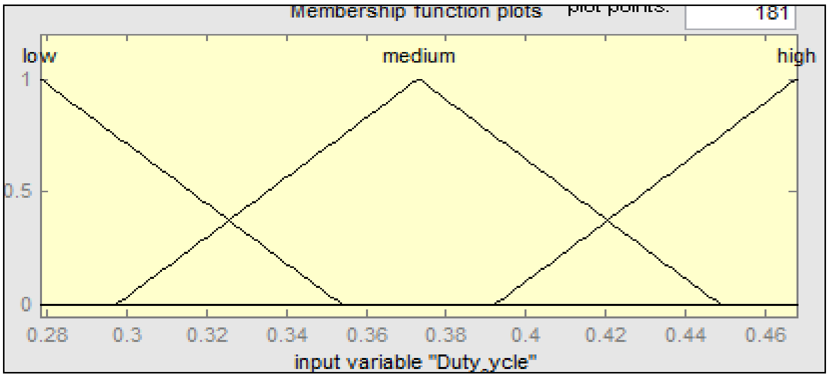

Fig. 7: *Plot Degree of Membership Function for Duty Cycle.*

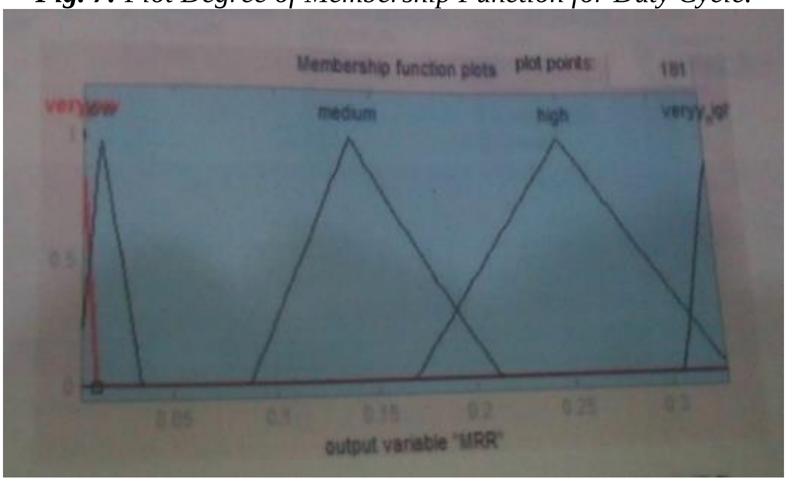

Fig. 8: *Plot Degree of Membership Function for MRR.*

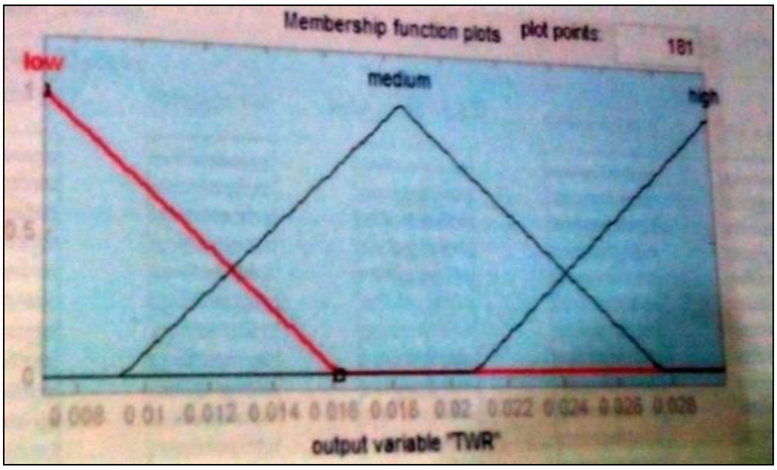

Fig. 9: *Plot Degree of Membership Function for TWR.*

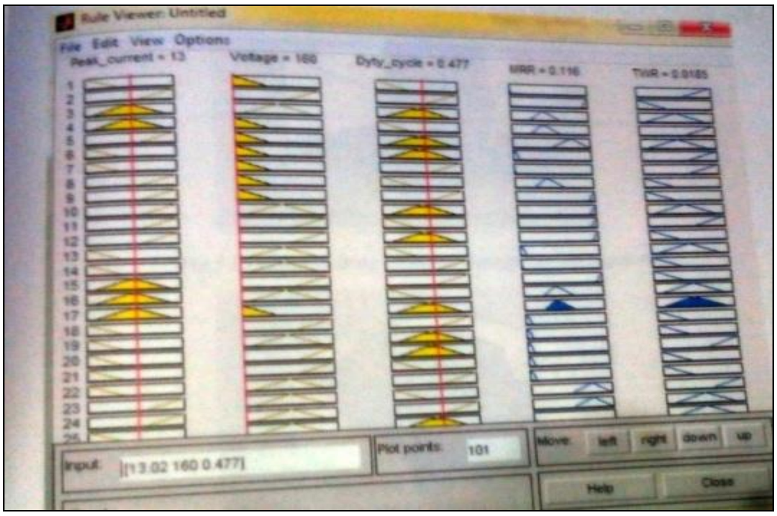

Fig. 10: *Fuzzy Rule Viewer.*

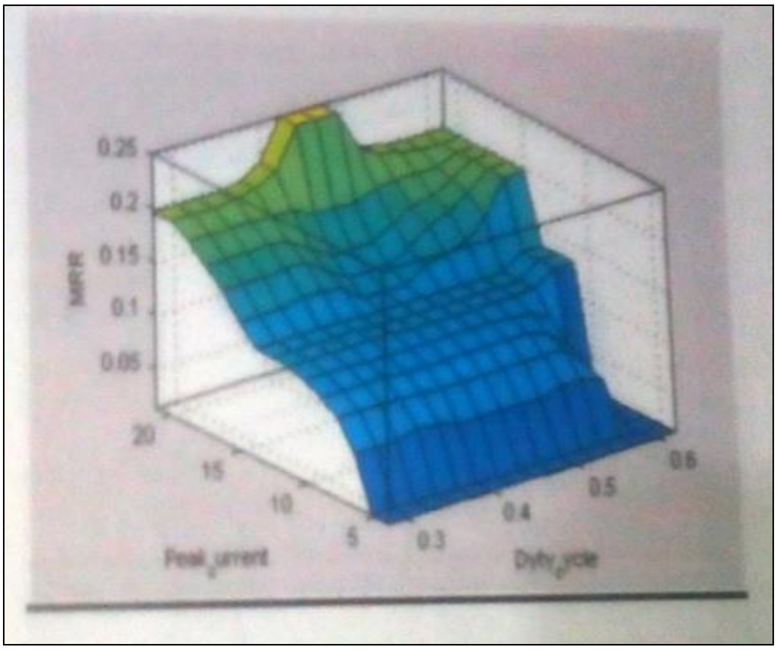

Fig. 11: *Effect of Peak Current and Duty Cycle on MRR.*

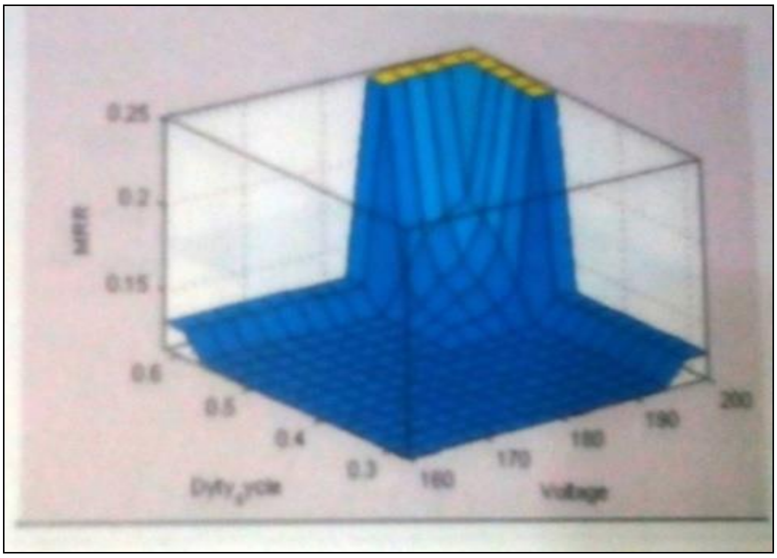

Fig. 12: *Effect of Voltage and Duty Cycle on MRR.*

Table 4: *A Part of Experimental and Fuzzy Modeling Results for Prediction of MRR.*

Sr No.	Peak Current	Voltage	Duty Cycle	Experimental Result of MRR	Modeling Result of MRR
1	4	160	0.278	0.007	0.00769
2	4	180	0.278	0.086	0.00769
9	21	200	0.278	0.0142	0.0151
13	13	160	0.477	0.12	0.116
19	4	160	0.680	0.1079	0.11
25	21	160	0.680	0.2157	0.25

Table 5: *A Part of Experimental and Fuzzy Modeling Results for Prediction of TWR.*

Sr No.	Peak Current	Voltage	Duty Cycle	Experimental Result of TWR	Modeling Result of TWR
1	4	160	0.278	0.029	0.027
2	4	180	0.278	0.024	0.0269
9	21	200	0.278	0.008	0.0099
13	13	160	0.477	0.016	0.0185
19	4	160	0.680	0.028	0.0099
25	21	160	0.680	0.027	0.0099

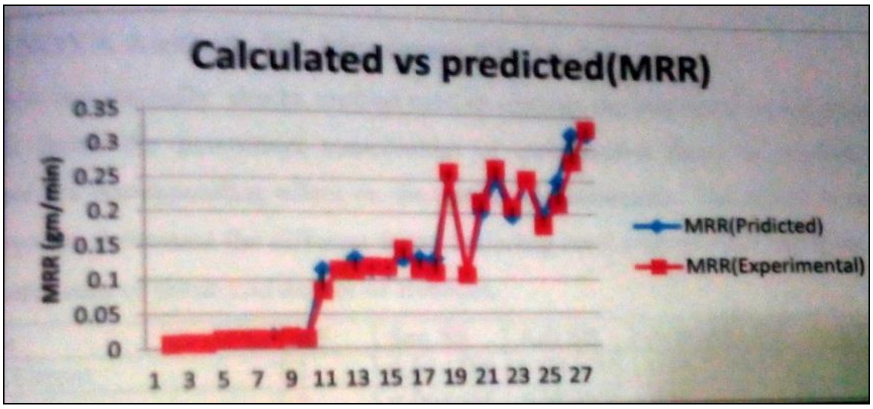

Fig. 13: *Calculated versus Predicted Graph for MRR.*

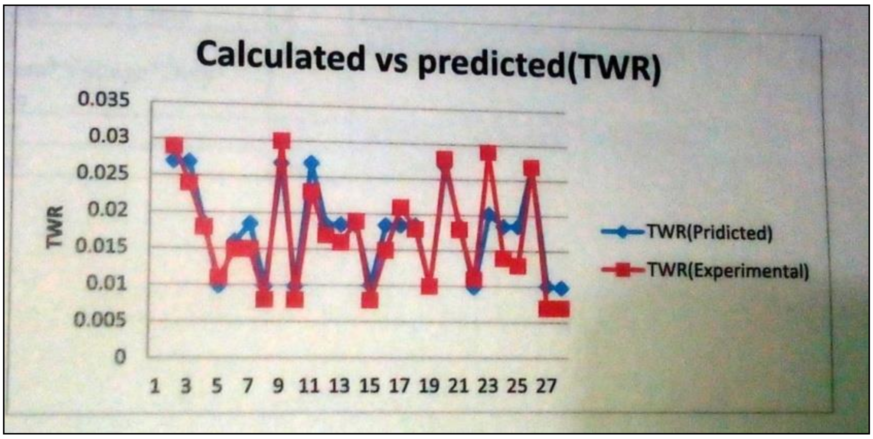

Fig. 14: *Calculated versus Predicted Graph for TWR.*

CONCLUSIONS

Observation indicates that fuzzy modeling results of EDM were in good agreement with experimental finding demonstrating approximately 90% prediction rate achieved. Experimental results indicate in the machining of INCONEL625, that the MRR increased with the increase in peak current and duty cycle, voltage is comparatively less influential parameter. In addition, TWR decreased with increase in duty cycle.

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