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An Investigation and Optimization of Electro Discharge Machining on Hastelloy C-276

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Abstract— ***The correct selection of manufacturing conditions is one of the most important aspects to take into consideration in the majority of manufacturing processes and particularly in the processes related to Electro Discharge Machining (EDM). EDM is capable of machining geometrically complex or hard material components, that are difficult-to-machine such as heat treated tool steels, composites, super alloys, ceramics, carbides, heat resistant steels etc. The present work is related to investigation of the effects of machining parameters such as current, pulse on time and pulse off time on the material removal rate (MRR) and surface roughness during Electro Discharge Machining of Hastelloy C-276 using a cylindrical shape copper electrode. Fuzzy logic based Genetic Algorithm has been used for parametric optimization of the process.***

Index Terms— ***EDM, GA, Fuzzy logic, Optimization.***

I. INTRODUCTION

The judicious selection of manufacturing conditions is one of the most important aspects to consider in Electro Discharge Machining (EDM). EDM process is employed widely for machining of parts where the problems of high complexity in shape, size and higher demand for product accuracy and surface finish are involved. Sheikh-Ahmad and Yadav [1] discussed the mechanistic modelling approach for predicting cutting forces in the milling process of carbon fiber reinforced composites. Specific energy functions were determined by regression analysis of experimental data and a cutting model was developed. It was shown that the model was capable of predicting cutting forces in milling of both unidirectional and multidirectional laminates. Model predictions were found to be in good agreement with the results of experiment. Palanikumar *et al.* [2] discussed on the optimization of machining parameters for surface roughness of glass fiber reinforced polymers (GFRP). Palanikumar [3] minimized the surface roughness in machining glass fiber reinforced (GFRP) plastics with a polycrystalline diamond (PCD) tool by using Taguchi and response surface methodologies. Basheer *et al.* [4] developed an experimental work on Al/SiCp composites leading to an artificial neural network-based (ANN) model to predict the surface roughness on the analysis of machined surface quality. With the unexposed experimental data set, the predicted roughness of machined surfaces based on the ANN model was found to be in very good agreement. Sait *et al.* [5] suggested desirability function based Taguchi analysis approach for optimizing the machining parameters on turning glass fiber reinforced plastic pipes. Hussain *et al.* [6] established a surface roughness prediction model for the machining of GFRP pipes using response surface methodology. Experiments were conducted through the established Taguchi's Design of Experiments on an all geared lathe using carbide (K20) tool. Cutting speed, feed, depth of cut, and work piece (fiber orientation) were considered as the cutting parameters. Using Response Surface Methodology, a second order mathematical model in terms of cutting parameters was developed. Rajasekaran *et al.* [7] applied fuzzy based modeling for machining of carbon fiber reinforced polymer (CFRP) composites to examine the influence of machining parameters combination so as to obtain a good surface finish in turning of carbon fiber reinforced polymer composite by cubic boron nitride (CBN) cutting tool and to predict the surface roughness values. The results indicated that in machining of CFRP composites, the fuzzy logic modeling technique could be effectively used for the prediction of surface roughness.

Hastelloy C-276 is usually a high temperature resistant alloy with high strength to weight ratio. It is a very hard alloy. Its' applications and advantages favours this material usage in defence and aerospace applications. The objective of the present work is thus to perform Electro discharge machining of Hastelloy C-276 material at different levels of peak current (I_p), pulse on time (T_{on}) and pulse off time (T_{off}). Investigations have been done for measurement of the performance characteristics such as material removal rate (MRR) and average surface roughness (R_a). Fuzzy logic based Genetic Algorithm technique has been used for parametric optimization of the process. MINITAB 17 and MATLAB R2010b have been used for the statistical analysis.

A. Experimental Scheme, Set up, Equipment and Work Material used

The experiments have been conducted in Electric Discharge Machine (fig.1a), model SPARKONIX mos25A (die-sinking type) with servo-head (constant gap) and reverse polarity. Kerosene oil is used as dielectric fluid. All the experimental samples have been machined with a circular

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shaped Cu tool electrode (fig.1b) by maintaining a reverse polarity.

Fig. 1: (a) Die Sinker EDM Model: SPARKONIX mos SN25

Fig. 1: (b) Circular copper electrode tool of 15 mm diameter

In the present work electro discharge machining has been performed on Hastelloy C-276. The chemical composition of Hastelloy C276 is given in the table 1.

Table-1: Composition of Hastelloy C-276.

C	Si	Mn	S	P	Cr	Fe	Co
0.007	0.042	0.346	0.011	0.013	15.532	5.326	0.745
Ti	Nb	V	Cu	Al	Mo	W	Ni
0.023	0.112	0.250	0.076	0.023	16.215	3.215	58.073

The developed design matrix is a five-level, three factor, central composite design consisting of twenty (20) sets of uncoded combination of the process parameters. Table 2 shows the 20 sets of parametric combinations along with the response characteristics.

Table-2: Process Parameters as per Central Composite Design and the Corresponding Machining Responses.

Exp No	I_p (A)	T_{on} (µs)	T_{off} (µs)	MRR (gm/min)	R_a (µm)
1	11.0000	5.0000	4.00000	0.10100	2.811
2	13.0000	7.0000	2.63641	0.20060	3.911
3	15.0000	9.0000	4.00000	0.24911	4.511
4	15.0000	9.0000	8.00000	0.21780	5.015
5	13.0000	7.0000	6.00000	0.20070	3.984
6	16.3636	7.0000	6.00000	0.28000	5.154
7	13.0000	7.0000	6.00000	0.20147	3.913
8	13.0000	3.6364	6.00000	0.11070	4.432
9	13.0000	7.0000	6.00000	0.20000	4.100
10	13.0000	7.0000	9.36359	0.18000	6.111
11	9.6364	7.0000	6.00000	0.09600	3.543
12	15.0000	5.0000	8.00000	0.19200	6.006
13	11.0000	9.0000	8.00000	0.13620	3.790
14	13.0000	10.3636	6.00000	0.15600	3.260
15	11.0000	9.0000	4.00000	0.10930	3.990
16	13.0000	7.0000	6.00000	0.21020	3.921
17	13.0000	7.0000	6.00000	0.20901	3.869
18	11.0000	5.0000	8.00000	0.10100	4.502
19	13.0000	7.0000	6.00000	0.20100	4.012
20	15.0000	5.0000	4.00000	0.21600	4.213

II. CALCULATION OF MULTI PERFORMANCE CHARACTERISTIC INDEX (MPCI) USING FUZZY LOGIC

In the present investigation the performance of the machining has been considered to be good if higher MRR and lower SR are achieved. Fuzzy logic has been employed for converting this multi-objective problem into a single objective one. All linguistic inputs are converted into linguistic output by using Fuzzy logic. The linguistic output is then converted to meaningful logical aggregation of multiple responses in terms of numeric value or single Multi-Performance-Characteristic Index (MPCI) by defuzzification. In the present investigation, the fuzzy inference system (FIS) consists of two inputs and a single output (fig.2). Three membership functions **(**figs. 3 - 4**)** have been assigned to each of the input variables (MRR and SR respectively). These three membership functions are: "Low", "Medium", and "High" respectively.

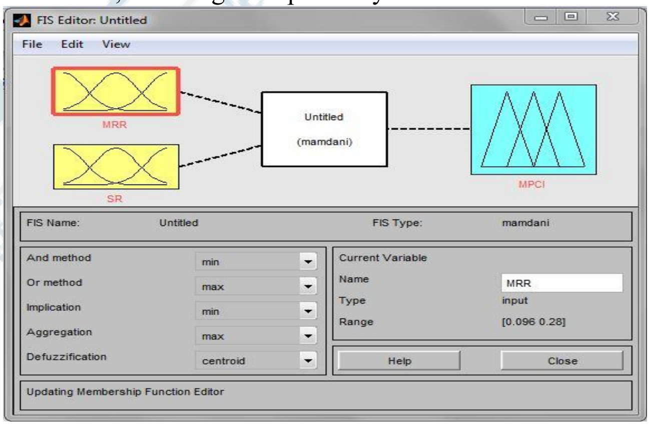

Fig.2 Proposed FIS model

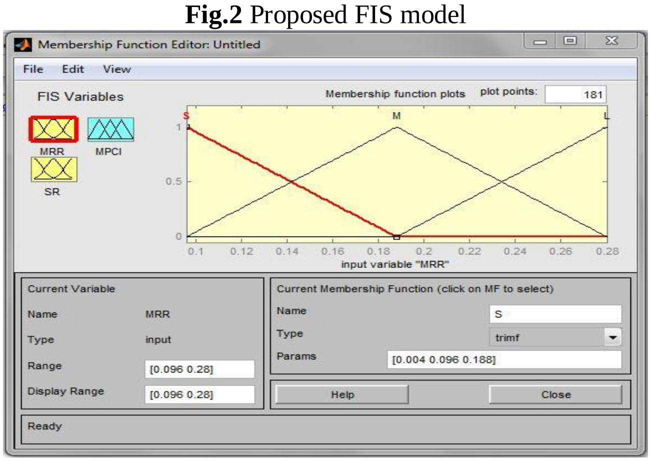

Fig. 3 Membership Functions for MRR

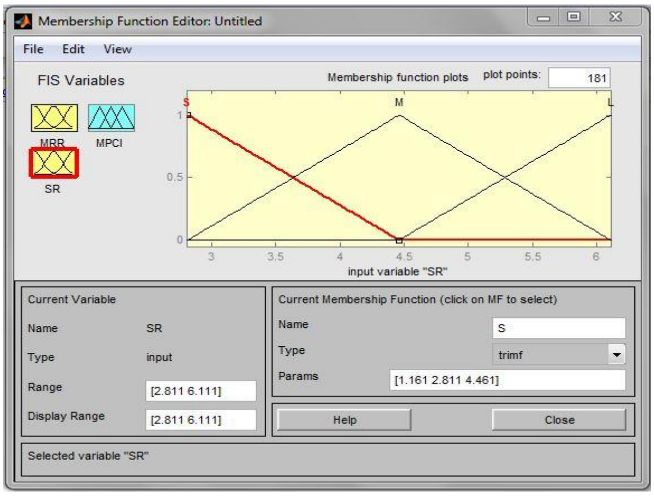

Fig. 4 Membership Functions for R_a

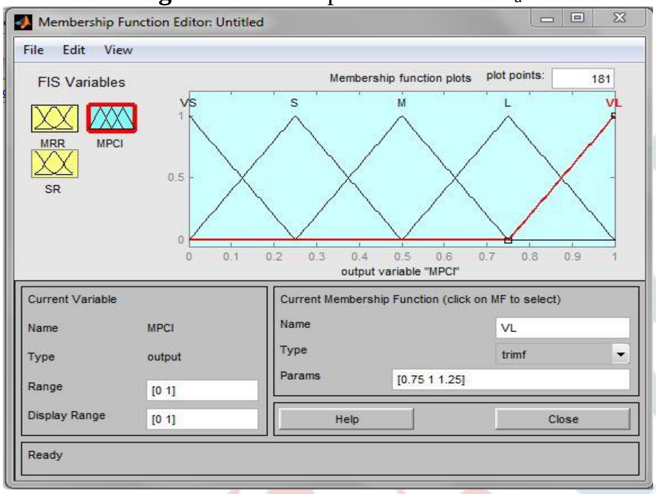

Fig. 5 Membership Functions for MPCI

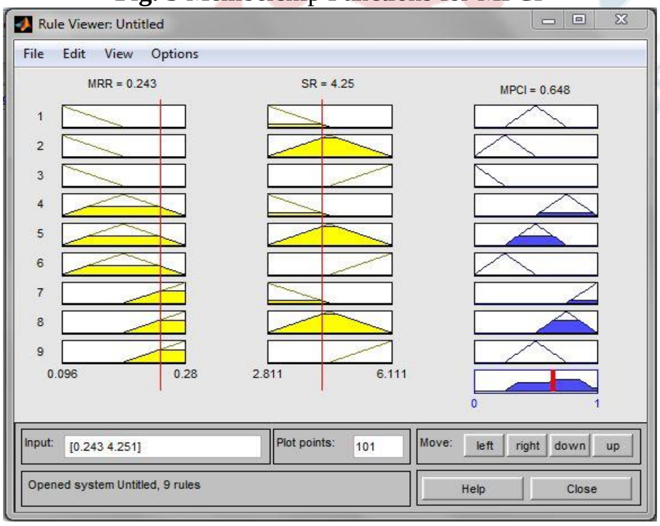

Fig. 6 Fuzzy rule based reasoning

Five membership functions i.e. “Very Low”, “Low”, “Medium”, “High” and “Very High” have been used for MPCI (Fig. 5). Fig. 6 shows fuzzy rule based reasoning. The MPCI values obtained at different parametric settings as per the design matrix are given in table 3.

Table- 3: Multi Performance Characteristics Index (MPCI)

Exp. No	MRR (gm/min)	R_a (μm)	MPCI
1	0.10100	2.811	0.519
2	0.20060	3.911	0.595
3	0.24911	4.511	0.646
4	0.21780	5.015	0.498
5	0.20070	3.984	0.585
6	0.28000	5.154	0.641
7	0.20147	3.913	0.595
8	0.11070	4.432	0.309
9	0.20000	4.100	0.569
10	0.18000	6.111	0.249
11	0.09600	3.543	0.386
12	0.19200	6.006	0.296
13	0.13620	3.790	0.476
14	0.15600	3.260	0.566
15	0.10930	3.990	0.387
16	0.21020	3.921	0.6
17	0.20901	3.869	0.606
18	0.10100	4.502	0.269
19	0.20100	4.012	0.582
20	0.21600	4.213	0.589

A regression model has been developed to understand the relationship in between MPCI and process parameters involved during Electro Discharge Machining or in other words Ip, Ton and Toff. The regression equation (Using uncoded units) obtained for MPCI is given as follows:

$$MPCI = -0.780 + 0.1580I_p - 0.0090T_{on} + 0.0823T_{off} - 0.00570I_p^2 - 0.01242T_{on}^2 - 0.01379T_{off}^2 + 0.00800I_p \times T_{on} - 0.00650I_p \times T_{off} + 0.01737T_{on} \times T_{off} \quad \text{-------------------------(1)}$$

(The constant and the coefficients are with consistent units)

III. PARAMETRIC OPTIMIZATION

Genetic Algorithm technique is applied in order to determine optimum level for each parameter for of larger-the-best MPCI. The developed regression model for MPCI (equation 1) is employed as the fitness function of Genetic Algorithm. The GA tool in MATLAB 2010 b has been used is used to run the GA optimization. The GA tool is run by changing the population size, reproduction cross over fraction, migration fraction to minimize the fitness/objective function. As the optimization problem is for larger-the-best type response, a unity negative factor is multiplied to fitness function to convert it into a minimization type problem. The fitness vs. generation/iteration is plotted at different generations. It is observed that the curve converges at generation 20 as shown in fig. 7. The optimal combination of process parameter and optimal value of responses are listed in table 4.

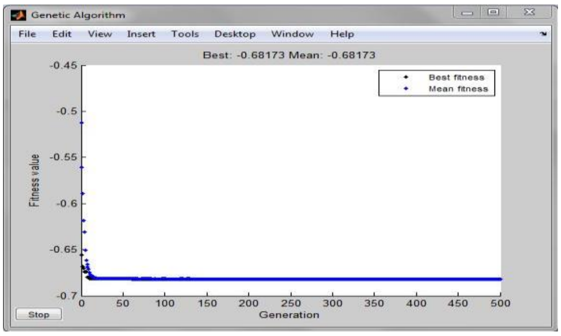

Fig. 7 Fitness vs. Generation graph

Table-4: Optimum parametric condition obtained from Genetic Algorithm

Input parameter		I_p (A)	T_{on} (µs)	T_{off} (µs)
Optimized parametric value	Machine value	15	7	4
	Original value	15	300	20

IV. CONFIRMATION TEST

It is required to run a confirmation run for checking the validity of the experiment. Hence, it is equally important to be able to predict the performance under the optimal condition before running the confirmation. Based on GA optimization, the predicted optimum condition for higher MPCI is I_p15 T_{on}7 T_{off} 4. Table 5 shows the experimental results for the predicted optimum parametric setting.

Table-5: Experimental results for the optimum parametric setting

Optimum parametric setting	MRR (gm/min)	R_a (µm)	MPCI
I_p15 T_{on}7 T_{off} 4	0.243	4.251	0.648

From the results of the confirmatory experiment shown in table 6 it is found that there is an improvement of 0.150 in overall MPCI. Thus Fuzzy based GA technique has been found to be an efficient method for determining the optimized parametric condition.

Table-6: Results of confirmatory Test

	Factor setting	Optimum condition	
		Predicted	Experimental
Level	I_p15 T_{on}9 T_{off}8	I_p15 T_{on}7 T_{off} 4	I_p15 T_{on}7 T_{off} 4
MPCI	0.498	0.681	0.648
Improvement of overall MPCI =(0.648 – 0.498)=0.150			

V. CONCLUSIONS

Based on the scope and limitations of the present investigation the following conclusions are drawn from the results of experiments and analysis of the data in connection with electro discharge machining of Hastelloy C-276.

- Three process parameters have been chosen in the present investigation viz. peak current, pulse on time and pulse off time. The response parameters are MRR and R_a. It is aimed to maximize MRR and minimize SR. The multi objective problem is converted into a single objective problem through the concept of Fuzzy Logic. The analysis through the concept is carried out for maximization of MPCI. Genetic Algorithm has been used for optimization of the process parameters. It has been found that the optimal parametric setting is Ip15 Ton7 Toff4.
- Confirmatory tests have validated the parametric settings determined by the above methodology.
- The approach can be recommended for continuous quality improvement and offline quality control of a process.

REFERENCES

[1] J. Sheikh-Ahmad and R. Yadav, "Model for Predicting Cutting Forces in Machining CFRP, International" Journal of Materials and Product Technology, vol.32 (2-3) pp.152-167, 2008.

[2] K.L. Palanikumar, R. Karunamoorthy and Kartikeyan, "Optimizing of Machining Parameters for Minimum Surface Roughness in Turning of GFRP Composites using Design of Experiments", Journal of Materials Processing Technology, vol.20 (4) pp.373-378, 2004.

[3] K. Palanikumar, "Application of Taguchi and Response Surface Methodologies for Surface Roughness in Machining Glass Fiber Reinforced Plastics by PCD Tooling", International Journal of Advanced Manufacturing Technology, vol.36 pp.19–27, 2008

[4] A. C. Basheer, U. A. Dabade, S. S. Joshi, V.V. Bhanuprasad, and V.M. Gadre, "Modeling of Surface Roughness in Precision Machining of Metal Matrix Composites using ANN", Journal of Materials Processing Technology, vol.197 pp.439–444, 2008

[5] A. N. Sait, S. Aravindan and A. N. Haq, "Optimization of Machining Parameters of Glass Fiber Reinforced Plastic (GFRP) Pipes by Desirability Function Analysis using Taguchi Technique", International Journal of Advance Manufacturing Technology, vol.43 pp.581-589, 2009.

[6] S.A. Hussain, V. Pandurangadu and K. Palanikumar, "Surface Roughness Analysis in Machining of GFRP Composites by Carbide Tool (K20)", European Journal of Scientific Research, vol.41 (1) pp.84-98, 2010

[7] T. Rajasekaran, K. Palanikumar and B.K. Vinayagam, "Application of Fuzzy Logic for Modeling Surface Roughness in Turning CFRP Composites Using CBN Tool", Production Engineering and Research Development, vol. 5 pp. 191-199, 2011.