Optimization of Electric Discharge Machining(EDM) process parameters using Grey Relational Analysis(GRA) for Incoloy 800HT

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***Abstract*— Optimization is techniques used in manufacturing condition to developed manufacturing process and important for manufacturing industries to get high quality of product at lower price. This paper investigate to optimized the various process parameters like pulse ON time, current and voltage in Electric discharge Machining(EDM) using L9 orthogonal array, To identify the variations in performance characteristic such as Material Removal Rate (MRR), Radial Over Cut(ROC) and Surface Roughness(SR) were calculated based on these experiments. White light spectroscopy was used to calculated the Surface Roughness of the machined surface of the Incoloy 800HT, these output values were optimized using Grey Relational Analysis(GRA) method. The preference values were obtained after the optimization processes. The readings for the experiment which had the highest preference value was selected as the optimized value.**

Keywords*— EDM, Incoloy 800HT,GRA, White light spectroscopy.

I. INTRODUCTION

The quality of a product is the main factor for showing growth of a company. The quality of the product mainly depends upon the material and process parameters. Incoloy 800,800H and 800HT is an austenitic iron-nickel-based super alloy that has good strength and high temperature [1]. For the ease of machining hard-to-machine materials with complex shapes, non-conventional machining processes are more capable than conventional machining [2]. Optimization technique plays a vital role to increase the quality of the product [3]. Incoloy 800HT will not become embrittled even after long periods of usage in the 1200-1600° F range where many stainless steels become brittle. Excellent cold forming characteristics typically associated with the nickel-chromium alloys are exhibited with 800HT. When cold formed extensively the grain size produces a visibly undulated surface called “orange peel”. Incoloy 800HT can be welded by the common techniques used on stainless steels. Hence, many authors have presented their works on the optimisation of process parameters for various machining processes. It have done EDM process optimization with multiple performance characteristics based on orthogonal array with grey relational analysis for Titanium grades with brass electrode[4]. The process of dry EDM with tubular copper tool electrode and mild steel work-piece [5]. The experiments was conducted according to L9 orthogonal array. It was concluded that current was the most significant factor on ultimate tensile strength and pressure for impact energy [6].

Grey relational analysis (GRA) has been used by many researchers for machining processes which include electric discharge machining [7], chemical mechanical polishing [8], determining condition of tool in turning [9], side milling [10], and flank milling [11] to analyse the performance of diamond tool carbide inserts in dry turning [12], and optimization of parameters in drilling [13].

The objective of this paper is to determine the optimal levels of the process parameters for Electric-Discharge Machining process. This work was done with Incoloy 800HT grade as work piece material and copper as tool electrode. The process parameters such as current, voltage and pulse ON time were optimized with the considerations of multiple performance characteristics such as material removal rate, radial over cut and surface roughness value on the work material. The experimental results are presented and discussed.

II. EXPERIMENTAL PROCEDURE

Incoloy800HT

Incoloy800HT is select as the work piece material dimensions 300x20x4mm and copper is used as the electrode material. ASTM grain size of Work piece material. The chemical compositions of work piece material is given in Table-1. The properties of electrode and image for electrode are shown in Table-2 and Fig-1 . The mechanical properties of material Y.S 200(MPa), UTS 531(MPa), hardness 126 Brinell.

TABLE-1 Chemical compositions of work piece material

Ni	Cr	Fe	C	Al	Ti	Al+Ti
30.0-35.0	19.0-23.0	39.5	0.06-0.10	0.25-0.60	0.25-0.60	0.85-1.20

TABLE-2 Properties of copper electrode material

Properties	**Value**
Density	8.92 $\times 10^{-3}$ g/mm³
Melting point	1083ºC
Poisson's ratio	0.26
Elastic modulus(E)	1.23×10^5 N/mm²
Diameter	6.103 mm

FIGURE-1 Image of copper electrode.

Machining was carried out in EDM machine the work piece Incoloy 800HT with copper material as the electrode. Machine is provided with pulse voltage. The pulse ON time were select from different current range and given as input using L9 orthogonal array and chosen parameters. The input value respectively Material removal rate, Surface roughness and Radial out cut was measured. shown Fig-2 image of machining process and Table-3 shown the working conditions of EDM.

FIGURE-2 Image of Machining process

TABLE-3 Working conditions of EDM

Working condition	**Description**
Work piece	Incoloy 800HT
Electrode	Copper
Current	4,8,12 amps
Voltage	2,4,6 volts
Pulse ON time	30,60,90 **µs**
Dielectric Medium	EDM oil

The control parameters at three various levels and their response parameters considered for performance characteristics in this process are shown in Table-4.

TABLE-4 Response and control parameters with three levels

Control Parameters	**Response Parameters** Material Removal Rate(mm³/min) , Radial Over Cut(mm) , Surface Roughness(**µm**)		
	Levels		
	1	2	3
Current(A)	4	8	12
Voltage(V)	2	4	6
Pulse ON time(**µs**)	30	60	90

III. GREY RELATIONAL ANALYSIS(GRA)

Grey relation analysis(GRA) a part of information is known and part of information is unknown comes under grey system. GRA gives us the complete information-from black through grey to white. It does not help to find the best solution but provide techniques for determining a good solution for real world problem and shown Table-5 in various response parameters.

TABLE-5 Various response parameters

Exp. No	Current (amps)	Voltage (volts)	Pulse ON time(**µs**)	MRR (mm³/min)	SR (**µm**)	ROC (mm)
1	4	2	30	1.21746	34.53	0.02005
2	4	2	60	0.62132	36.15	0.02625
3	4	2	90	0.40302	23.98	0.0536
4	8	4	30	6.21746	44.87	0.3267
5	8	4	60	2.569269	45.28	0.14605
6	8	4	90	1.62888	39.05	0.1018
7	12	6	30	9.67254	43.66	0.4059
8	12	6	60	5.64231	62.71	0.35625
9	12	6	90	3.736356	46.99	0.2145

Normalized Values

The Grey Relational Analysis [14] Pre- processing of the data was first performed for normalizing the raw data for analysis. This shown in table. The equation to avoid the effect of adopting different units and to reduce the variability. The normalized output parameter corresponding to larger the better criterion can be expressed as equation 1.

EQUATION 1

$$\text{Normalized}=\frac{\text{Present value}-\text{Minimum}}{\text{Maximum}-\text{Minimum}} \text{ (for maximizing)}$$

$$\text{Normalized}=\frac{\text{Maximum}-\text{Present value}}{\text{Maximum}-\text{Minimum}} \text{ (for minimizing)}$$

TABLE-6 Normalized values

Exp.No	Current(A)	Normalized values		
		MRR(mm³/min)	SR(μm)	ROC(mm)
1	4	0.087862155	0.272399	0
2	4	0.023550302	0.314227	0.016068
3	4	0	0	0.086951
4	8	0.627264411	0.539375	0.794739
5	8	0.23369592	0.549961	0.326552
6	8	0.13224633	0.389104	0.21187
7	12	1	0.508133	1
8	12	0.565216969	1	0.871323
9	12	0.359601792	0.594113	0.503952

Grey Relational Co-efficient(GRC)

The grey relational co-efficient [15] is calculate to express the relationship between the ideal and actual normalized value. By using the equation 2. It is given in the table-7.

EQUATION 2

$$\text{GRC}=\frac{\text{weight of function}}{\text{DEL}+(\text{weight}*1)}$$

Grey Relational Grade(GRG)

The grey relational grade(γ)[16] was determined by average the grey relational co-efficient corresponding to each performance characteristic. The response process depends on the calculated grey relational grade. The GRG can be expressed as equation 3. It is given in the table-7.

EQUATION 3

$$\gamma(i)=\frac{1}{n}\sum_{=1}^{Q} i(k)$$

(3)

where, Q= total quantity of responses

n= quantity of output responses

TABLE-7 Grey Relational Co-efficient and Grey Relational Grade.

Exp. No	Current (A)	Grey Relational Co-efficient (GRC)			Grey Relational Grade	Rank
		MRR (mm³/min)	SR (μm)	ROC (mm)		
1	4	0.354073	0.407298	0.333333	0.364902	8
2	4	0.33865	0.421666	0.336943	0.365753	7
3	4	0.333333	0.333333	0.353845	0.34017	**9**
4	8	0.572911	0.520495	0.708957	0.600788	3
5	8	0.39485	0.526294	0.426095	0.44908	5
6	8	0.365563	0.450087	0.38816	0.40127	6
7	12	1	0.5041	1	0.8347	**1**
8	12	0.534883	1	0.795321	0.776735	2
9	12	0.438443	0.551945	0.501984	0.497458	4

GRG is obtained for the equivalent set of process parameters compared to other sets, it is considered as the most favorable optimal setting. The EDM were optimized for higher material removal rate, lower surface roughness and lower radial over cut value on the work material.

IV. RESULTS AND DISCUSSION

EDM machining process on Incoloy 800HT was performed according to L9 orthogonal array to investigate the optimizing of various machining process parameters, namely, Current, Voltage and Pulse ON time on the output values, Material removal rate, Surface roughness and Radial over cut on the output responses. finally, calculated the surface roughness of material using White light spectroscopy those output values are optimized based on the Grey Relational Analysis(GRA) method. The optimal parameters with its levels were conducted to evaluate quality of characteristics for EDM of Incoloy 800HT.

Various models using GRA

By using GRA complicated optimization, The higher grey relational grade will have better process parameters response characteristics. Graph shows the grey relational Co-efficient and Grey relational grade for all experiments. Hence, it is clear that experiment has the optimal parameters setting for best response characteristics, such as Material removal rate, Surface roughness and Radial over cut. The Fig-3 shown the Grey relational grade.

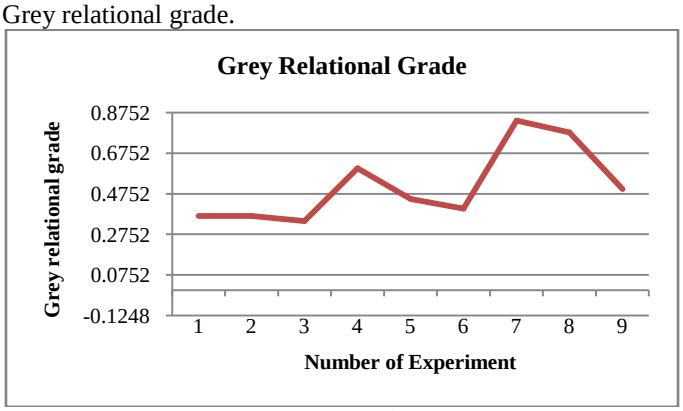

FIGURE-3 Grey Relational Grade for MRR, SR and ROC

White light spectroscopy

The surface roughness sample was analyzed on machine surface by spectroscopy. Each of transitions in absorption spectrum creates a pair of diagonal peaks in 2D spectrum. The negative peak exactly on the diagonal (BLUE) corresponds to photobleaching of direct bandgap transition, the blue shifted positive peak along the axis is from an excited absorption. select the sample 7 and sample 3 base on Grey relational Grade rank order. Fig-4 sample 7 and Fig-5 sample 3 shown in 3D and 2D surface roughness.

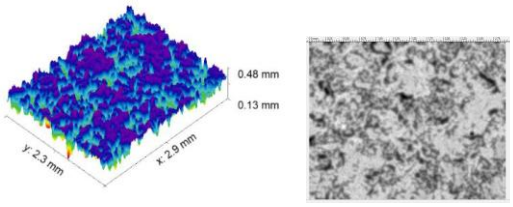

FIGURE-4 3D and 2D Surface Roughness Image(sample 7)

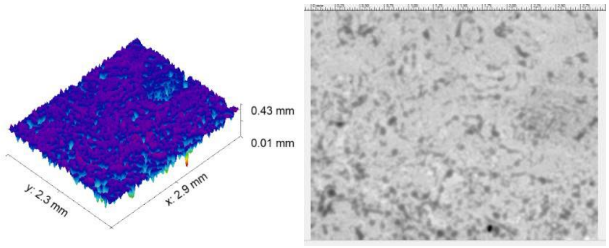

FIGURE-5 3D and 2D Surface Roughness Image (Sample 3)

The sample 7 having higher Surface roughness values table. so, the rank 1 get high roughness vale compare to the rank 9 sample.

TABLE-8 Surface Roughness values

Exp.no	Surface Roughness (µm)
Sample 7	43.66
Sample 3	23.98

The various result value is based on the machining process in EDM. They consider the optimized process parameters can be analysis in GRA method and identify the surface roughness value by using white light spectroscopy.

V. CONCLUSION

In this study L9 orthogonal array with grey relational analysis has been used to optimizing the input parameters such as current, voltage and pulse ON time . Multi attribute optimization has been performed using GRA (Grey relational analysis) to determine the most significant set of process variables. The response parameters considered were MRR (Material removal rate), SR (Surface Roughness) and ROC (Radial over cut). White light spectroscopy was used to measure the surface roughness of the machined surface(sample 7 and 3) of Incoloy 800HT during EDM process. The optimal setting of process parameters was found to be current(amps) = 12 voltage(volts)=6 and pulse ON time(µs) =30 in GRA. Therefore the models are appropriate to establish the best possible solution for the set of input parameters depending upon the required performance characteristics. The outcome of the present research work will be a considerable aid to the industries for quality improvement in processing.

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