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OPTIMIZATION OF ELECTRICAL DISCHARGE MACHINING PARAMETERS FOR INCONEL 718 USING GREY RELATIONAL ANALYSIS

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ABSTRACT

In this work Electrical Discharge Machining (EDM) experiments were conducted based on the L16 orthogonal array are carried out on inconel 718 material using 99.9% pure copper electrode tool material with kerosene as a dielectric fluid to discuss the effect of five process parameters pulse on time (T_{ON}), pulse off time(T_{OFF}), current(A), flushing pressure (P) and electrode tool geometry(Geo) on the process responses of material removal rate(MRR), tool wear rate(TWR) and surface roughness(SR) and all data's are optimized using multi objective optimization technique of Grey relational analysis(GRA). Experimental results show that the current and pulse on time are most influencing parameters that are directly proportional to MRR and inversely proportional to TWR, SR. The Rectangle tool geometry was found best in all aspects.

Key words: *Electrical Discharge Machining [EDM], Material Removal Rate [MRR], Tool Wear Rate [TWR], Surface Roughness [SR], Grey Relational Analysis (GRA.)*

1. Introduction

Electrical Discharge Machining [EDM] is used to machine hard metals for which traditional machining techniques are ineffective. EDM process using thermal energy for material removing as well as absence of direct contact between the tool and the workpiece avoid the mechanical stresses [residual], chatter and other vibrations irrespective of materials hardness. As reported by many authors on process analysis for optimization of parameters to identify the effect of operating variables on archiving the desired machining characteristics [5] - [7] using statics technique as well as soft computing techniques [8] and among the EDM input process parameters the most influencing factor was found to be Peak current and pulse on time to optimize the MRR, TWR, SR [6]-[7]

Inconel 718, a nickel based super alloy is having high corrosion resistance and high strength with outstanding weldability, including resistance to post weld cracking. Inconel 718 is widely used gas turbines, rocket engines. This alloy difficult to machine due to its poor thermal properties by conventional machining, to overcome a non conventional machining method EDM is chosen for machining Inconel 718. The EDM machining process parameters influences, interactions and its optimization was done by many authors [7] using different kind of electrode materials [1], [3] to machine inconel 718 and developed various statistical [2] and soft computing techniques [8].Naricies et al. [5] has studied the influence of tool geometry and surface quality of AISI H13 tool steel using copper electrode in EDM and parameters were optimized using Taguchi methods. They concluded that MRR is mainly affected by current followed by pulse off time and SR is influenced by current. But tool geometry has no influence on MRR and SR. They suggested that the S and R geometry of tool are best suited for minimum TWR. Triangle shape tool geometry is not suitable for complex geometries, because improper wear observed on surface of the material. M.S.Sohani [4] et al., investigated the effect of tool geometry with various size factor consideration in die sink EDM process. Based on the experimental results, the mathematical models were developed using response surface methodology. It was concluded that, the circular tool geometry was best suitable for higher MRR and Lower TWR followed by triangular, rectangular and square cross sections. Current and pulse on time are highly significant on MRR.

In this study focuses on investigating the influence of EDM parameters and electrode geometry on feature accuracy in super alloys for mould fabrication and deals with the use of multi objective optimization technique based on gray relational analysis (GRA) approach in machining of inconel 718 materials by

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EDM for maximizing the MRR and minimize the TWR&SR.

2. Experimental Work

The 3mm thickness sheets of inconel 718 plates were cut into the required size 100X50X3 mm using wire cut EDM process. The drilling operations (through hole) were performed with copper electrode tool material with different tool geometries like circle, S, R and triangle using Electronica EMS -5030 die sinking EDM machine. After completion of each machining operations, the workpiece and electrode were blown by compressed air using air gun to ensure no debries and dielectric were present. The weight of the workpiece and electrodes were measured using precise electronic balance machine with an accuracy of 10 µg before and after the machining process. In the present study, four level process parameters i.e. Pulse on-time [TON=38,63,83&93µs],pulse-off-time [TOFF=2,7,8&9 µs], current[I=4,12,14&15A], flushing pressure(2,5,7&9 kgf/cm2) and Tool geometry(circle, S, R and triangle) are considered. The rest of EDM parameters kept as constant during the experimentation.

3. Optimization steps using Grey Relational Analysis

In this paper, the original response values are transformed to S/N ratio values. S/N ratio for the corresponding responses using the following formula1& 2 are calculated. (Where n=number of replications yij=observed response value where i=1, 2 ...n; j=1, 2...k). Then the normalized S/N ratio data in grey relation analysis using equation 4&5 and the grey relational co-efficient for the normalized S/N ratio values using equation 7. The grey relational grade is generated using equation 8…

$$\bar{\gamma}_j = \frac{1}{k}\sum_{i=1}^{m}\gamma_{ij} \qquad (8)$$

Where $\bar{\gamma}_j$ the grey relational grade for the jth experiment and 'k' is the number of performance characteristics. The optimal factor and its level combination is estimated on the effect of factor 'i', then the average of grade values (AGV) for each Level'j', denoted as AGVij, and the effect, Ei is defined as

$$\mathrm{E_i} = \max\left(\mathrm{AGV_{ij}}\right) - \min\left(\mathrm{AGV_{ij}}\right) \qquad (9)$$

If the factor i is controllable, the best level j*, is determined by

$$\mathbf{j^*} = \max_{\mathrm{j}}\left(\mathrm{AGV_{ij}}\right) \qquad (10)$$

Finally the ANOVA was done for identifying the significant factors.

Larger - the – better:

$$\text{S / N ratio } (\eta) = -10\log_{10}\left(\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_{ij}^2}\right) \qquad (1)$$

Smaller - the – better:

$$\text{S / N ratio } (\eta) = -10\log_{10}\left(\frac{1}{n}\sum_{i=1}^{n}y_{ij}^2\right) \qquad (2)$$

Nominal - the – best:

$$\text{S / N ratio } (\eta) = -10\log_{10}\left(\frac{\mu^2}{\sigma^2}\right) \qquad (3)$$

where ,

$$\mu^2 = \frac{y_1 + y_2 + y_3 + ... + y_n}{n} \;;\quad \sigma^2 = \frac{(y_i - \bar{y})^2}{n-1}$$

Larger - the – better:

$$Z_{ij} = \frac{y_{ij} - \min(y_{ij}, i = 1,2,...,n)}{\max(y_{ij}, i=1,2,...,n) - \min(y_{ij}, i=1,2,...,n)} \qquad (4)$$

Smaller - the – better:

$$Z_{ij} = \frac{\max(y_{ij}, i = 1,2,...,n) - y_{ij}}{\max(y_{ij}, i=1,2,...,n) - \min(y_{ij}, i=1,2,...,n)} \qquad (5)$$

Nominal - the – best:

$$Z_{ij} = \frac{\max(y_{ij} - Target) - \min(\left|y_{ij} - Target\right|, i=1,2,...,n)}{\max(\left|y_{ij} - Target\right|, i=1,2,...,n) - \min(\left|y_{ij} - Target\right|, i=1,2,...,n)} \qquad (6)$$

Grey Relational Co-Efficient

$$\gamma(y_o(k), y_i(k)) = \frac{\Delta_{\min} + \xi\Delta_{\max}}{\Delta_{oj}(k) + \xi\Delta_{\max}} \qquad (7)$$

4. Results and Discussions

From Table 1, the high MRR and lower TWR, SR was obtained for different process parameters with different tool geometry. To obtain unique result, the multi objective optimization technique desirability approach was applied. From Table 2 and we obtain the optimal parameter conditions Pulse On time (level 2), Pulse Off time (level 1), Peak current (level 4) , Flushing Pressure (level 4) and tool shapes (level 4) for copper electrodes . Based on the experimental results, the input parameters and its individual parameters contributions are identified using ANOVA technique and the values are presented in Table.3. From Table 3, it is clear that the effect of peak current (66.44%), pulse on time (16.558%) followed by flushing pressure (15.11%).pulse off time have less influences. The tool geometry has no influences on copper electrode. We observed that the current and pulse on time is the most influential factors followed by

Table 1: S/N Ratios and Grey Grade Values

S. No	T_{ON} (μs)	T_{OFF} (μs)	A (Amp)	P (kg/cm^2)	GEO	MRR (g/min)	TWR (g/min)	SR (μm)	S/N RATOIS			NORMALIZED VALUES			GREY VALUES			Grey Grade
									MRR	TWR	SR	MRR	TWR	SR	MRR	TWR	SR	
1	38	2	4	5	C	0.03	0.01	2.98	-28.9	47.9	-9.49	0.43	0.13	0.52	0.46	0.36	0.51	0.44
2	38	7	12	7	S	0.25	0.01	4.46	-11.9	59.9	-12.9	1.00	0.21	0.84	1.00	0.29	0.76	0.68
3	38	8	14	8	R	0.15	0.01	3.65	-16.4	43.4	-11.2	0.85	0.26	0.68	0.77	0.41	0.61	0.59
4	38	9	15	9	T	0.19	0.07	5.44	-14.3	23.0	-14.7	0.91	0.86	1.00	0.86	0.78	0.71	0.61
5	63	2	12	8	T	0.23	0.01	4.87	-12.6	38.1	-13.7	0.97	0.42	0.91	0.95	0.46	0.85	0.75
6	63	7	4	9	R	0.10	0.01	2.76	-19.2	45.1	-8.8	0.76	0.21	0.45	0.67	0.39	0.48	0.51
7	63	8	15	5	S	0.23	0.01	3.49	-12.4	45.7	-10.8	0.98	0.19	0.64	0.97	0.38	0.58	0.64
8	63	9	14	7	C	0.20	0.01	5.10	-13.9	40.7	-14.1	0.93	0.34	0.94	0.88	0.43	0.90	0.74
9	83	2	14	9	S	0.21	0.01	4.56	-13.4	38.7	-13.1	0.95	0.40	0.86	0.91	0.45	0.78	0.71
10	83	7	15	8	C	0.21	0.01	4.16	-13.2	42.3	-12.3	0.95	0.29	0.78	0.92	0.41	0.70	0.68
11	83	8	4	7	T	0.01	0.01	4.64	-40.5	63.6	-13.3	0.04	0.22	0.87	0.34	0.27	0.79	0.47
12	83	9	12	5	R	0.12	0.01	4.25	-18.4	40.5	-12.5	0.78	0.35	0.80	0.69	0.435	1.00	*0.88*
13	93	2	15	7	R	0.17	0.01	4.86	-14.9	38.0	-13.7	0.89	0.42	0.91	0.83	0.46	0.84	*0.71*
14	93	7	14	5	T	0.09	0.01	2.73	-20.5	41.0	-8.8	0.71	0.33	0.46	0.63	0.429	0.48	0.51
15	93	8	12	9	C	0.11	0.01	4.69	-18.8	41.6	-13.4	0.77	0.32	0.88	0.686	0.42	0.80	0.64
16	93	9	4	8	S	0.00	0.11	1.55	-41.8	68.5	-3.8	1.00	0.46	0.00	0.33	0.25	0.33	0.30

Table 2: Average Grey Scale Values Effect (AGV)

FACTORS/ LEVELS	1	2	3	4	AGV EFFECT (E_i)	RANK	OPTIMUM LEVEL (J^*)
TON(μs)	0.652	0.665	0.621	0.544	0.1304	2	2
TOFF(μs)	0.659	0.599	0.588	0.637	0.0702	4	1
A(Ampere)	0.435	0.674	0.642	0.731	0.2959	1	4
P(kg/cm^2)	0.557	0.653	0.585	0.688	0.1205	3	4
GEOMETRY	0.628	0.588	0.611	0.068	0.656	5	3

Table 3: ANOVA Table

Factor	Sum of Square (SS)	DOF	Mean Square(MS)	F Calculated	F Tabulated	% of Contribution
TON(μs)	0.0498	3	0.0166	18.3365		16.558
TOFF(μs)	0.0029	3	0.0098	1.08588		0.9806
A(Ampere)	0.1999	3	0.0667	73.5775		66.442
P(kg/cm^2)	0.0454	3	0.0152	16.7394	9.277	15.116
GEOMETRY	0.0000	-	-	-		-
ERROR	0.0027	3	0.0091			-
TOTAL	0.3009	15				100%

flushing pressure and pulse off time. High MRR is obtained at high peak current and high pulse on time. It is due to their dominant control over the input energy i.e., with the increase in pulse current generates strong spark which create the higher temperature and crater causes the more material to melt and erode form the work piece, rough surface in the work piece. It was also concluded by researchers that MRR cannot be increased by increasing the pulse on time; a suitable combination of peak current is also needed for increasing rate of removing unwanted material from the work piece. The Rectangle tool geometry has obtained the best results compared to other tool geometry. For the confirmation test, the experiments were conducted with the optimized machining parameters and it was found that the MRR is 0.251, TWR is 0.001 and SR is 1.554. The predicted values of MRR, TWR and SR are o.249, 0.001, and 1.551 respectively.

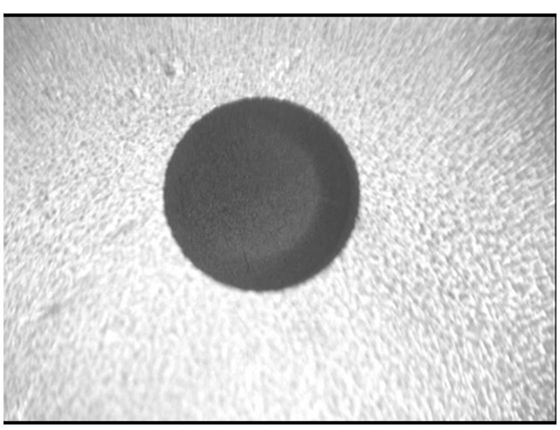

Fig. 1 Drilled Macroscopic View

Fig.1shows the drilled macroscopic view of copper electrode is given.

It shows that there is a closer agreement between measured and predicted values and the model is validated with 10% of error which is experimentally reasonable.

5. Conclusions

Based on the EDM parameters for machining Inconel 718 considered in this study, the following points are deduced. The optimization of EDM processes to obtain the favorable outputs was achieved through multi objective optimization using the desirability analysis. In the analyses, EDM peak current has the most significant parameter followed by pulse on time. The next influencing factor in this process is Rectangle tool geometry for copper electrode. Rectangle tool geometry is very suitable to get maximum MRR and Lower TWR, SR for Inconel 718 materials. Predicted results confirmed higher material removal rate lesser tool wear rate and surface roughness.

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