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MULTI RESPONSE OPTIMIZATION OF PROCESS PARAMETERS USING RESPONSE SURFACE METHODOLOGY IN EDM OF INCONEL 825

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Abstract - Now days, mass production of complicated shapes of different components with high accuracy is very difficult and takes much time by conventional machining process. To get- rid of above said difficulties, Electrical Discharge Machine (EDM) is the one nonconventional machining process which is used very widely. In EDM, it is necessary to optimize the process parameters like pulse on-time, pulse off- time, discharge current, voltage, for maximization of Material Removal Rate (MRR) for INCONEL 825. Basically (EDM) is a well-established nonconventional machining process, used for manufacturing geometrically complex or hard and electrically conductive material parts that are extremely difficult-to-cut by other conventional machining processes. Erosion pulse discharge occurs in a small gap between the work piece and the electrode. This removes the unwanted material from the parent metal through melting and vaporizing in presence of dielectric fluid. Presence of metal particles in dielectric fluid diverts its properties, which reduces the insulating strength of the dielectric fluid and increases the spark gap between the tool and work piece. As a result, the process becomes more stable and surface finish increases. The EDM process is mainly used for making of dies, moulds, parts of aerospace, automotive industry and surgical components etc. For this purpose Response Surface methodology is adopted to determine the process parameter that optimizes the best machining process.

Keywords- EDM, ANOVA, Multi response optimization, MRR and Machinability

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I. INTRODUCTION

Electrical Discharge Machine (EDM) is now become the most important accepted technologies in manufacturing industries since many complex 3D shapes can be machined using a simple shaped tool electrode. EDM is an important ‘non-tradition manufacturing method’, developed in the late 1940s and has been accepted worldwide as a standard processing manufacture of forming tools to produce plastics moldings, die castings, forging dies and etc. EDM technology is increasingly being used in tool; die and mould making industries, for machining of heat treated tool steels and advanced materials (super alloys, ceramics, and metal matrix composites) requiring high precision, complex shapes and high surface finish. Traditional machining technique is often based on the material removal using tool material harder than the work material and is unable to machine them economically. An EDM is based on the eroding effect of an electric spark on both the electrodes used. EDM actually is a process of utilizing the removal phenomenon of electrical-discharge in dielectric. Therefore, the electrode plays an important role, which affects the material removal rate and the tool wear rate.

A considerable amount of work has been reported by the researchers on the measurement of EDM performance on the basis of MRR, TWR, RWR, and SR for various types of steels. Rao et al. [1] studied the influence of process parameters on EDM of MDN 250 steel. They have considered discharge current, pulse on time, and duty factor as performance measures whereas process parameters are MRR and SR. However, in their study, parametric optimization was not done. TWR and RWR ratios were not considered. Furthermore, they extended their studies and developed a hybrid model for SR is to predict

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the behavior of the MDN 250 steel [2]. In EDM, for optimum machining performance measures, it is an important task to select proper combination of machining parameters [3].

Inconel 718 is a high strength, temperature resistant (HSTR) nickel-based super alloy. It is extensively used in aerospace applications, such as gas turbines, rocket motors, and spacecraft as well as in nuclear reactors, pumps and tooling. Inconel 718 is difficult to machine, because of its poor thermal properties, high toughness, high hardness, high work hardening rate, presence of highly abrasive carbide particles and strong tendency to weld to the tool to form build up edge [4]. Hole making has long been recognized as one of the most important machining processes. Approximately 50 to 70% of production time is spent in making holes [5]. The term 'deep hole' refers to a depth to diameter equal to five or greater. As the depth-todiameter ratio increases, it becomes extremely difficult to produce such holes, especially, in super alloys like Inconel 718. The earlier studies on machinability of Inconel 718 were mainly on turning and milling operations. Only very little published information is available on drilling studies of Inconel [6].

Kao and Hocheng [11] obtained grey relational grade using grey relational analysis while electrochemical polishing of the stainless steel. Optimal machining parameters were determined by the grey relational grade as the performance index. They observed that the performance characteristics such as surface roughness and passivation strength are improved. Singh et al. [12] suggested that orthogonal array (OA) with grey relational analysis is useful for optimisation of multiple response characteristics which is more complex compared to optimization of single-performance characteristics. They obtained optimal EDM parameters setting of metal removal rate, tool wear rate, taper, radial overcut and surface roughness while EDM of Al–10%SiCP as-cast metal matrix composites

In the present work, experiments have been conducted on EDM machine to identify effect of process parameters in machining of HSS and INCONEL 825. Response surface methodology was used to analyse the experimental results of surface roughness, MRR and tool wear rate. Multi response optimization technique is also used to optimize the process parameters.

2. Materials and Experimental procedure

In the experiments to obtain fine surface finish, die-sinking and milling micro-EDM was conducted using 500 μm W electrodes on the surface under different machining conditions. In the EDM of Inconel825, selection of electrode polarity is important. For this reason, the electrode polarity is firstly selected. In the EDM, positive electrode polarity resulted in extensive electrode wear compared with material removal rate from the workpiece. On the contrary, negative electrode polarity gives much better surface finish with comparatively higher material removal rate, lower electrode wear and controlled performance. Hence, the experiments were carried out with the electrode as negative polarity. In the process the spark always occurs at the closest point between the electrode and the workpiece. Thus if the surface of the electrode facing the workpiece is rough then the machining depth may not be equal to the anticipated depth. As shown in the Figure 1, Experiments were carried out at different levels of current, Ton, Toff and voltages. Workpieces used in this work are shown in the Figure 2. Experimental results of surface roughness, tool wear and MRR are given in the Table 1 for Inconel825.

Figure 1. Experimental set up of EDM

Figure 2. Inconel825 work pieces

III. RESULTS AND DISCUSSION

Experimental results of the responses, metal removal rate, tool wear rate and surface roughness are presented in the Table 1. The experimental results were analyzed using response surface methodology to identify significant parameters on the responses.

Table 1. Experimental results of Inconel825

S. No.	I	T_{on}	T_{off}	V	T	MRR	TWR	R_a
1	15	7	7	40	7.9598	32.2823	0	8.559
2	15	8	8	60	10.2922	24.9665	0.00388	9.599
3	15	9	9	70	12.2283	21.0136	0	4.519
4	15	10	10	80	20.2422	12.6943	0	4.960
5	20	7	8	70	18.043	14.2415	0.0066	10.64
6	20	8	7	80	9.5562	26.8894	0	9.320
7	20	9	10	40	7.0108	36.6521	0.00285	6.959
8	20	10	9	60	4.5485	56.4935	0	10.24
9	25	7	7	80	8.9725	28.6387	0.0189	6.680
10	25	8	9	70	7.2455	35.4648	0.0055	4.459
11	25	9	7	60	3.6093	71.1941	0	5.680
12	25	10	8	40	3.2693	78.5981	0.00305	4.063
13	30	7	9	60	5.8297	44.0778	0.0445	7.720
14	30	8	9	40	3.2608	78.803	0.0276	8.719
15	30	9	8	80	5.313	48.3645	0.00564	4.939
16	30	10	7	70	3.0035	85.5538	0	8.919

3.1 Analysis of MRR

In the present work, analysis of Variance (ANOVA) was carried out to identify significant parameter on the MRR. The ANOVA for the MRR was carried out at confidence level of 95%. Then the responses which are having p value less than the 0.05 are said to be significant.

From the Table 2, we can say that Current, T on, T off, voltage all are significant effective on the material removal rate because of p value of current ,T on, T off and voltage are 0.0043, 0.0095, 0.0146 and 0.0046 respectively.

Table 2. ANOVA table for MRR

Source	S S	df	M S	f-value	p-va;ue
A-I	985.984	1	985.984	24.284	0.0043
B-T on	675.196	1	675.196	16.629	0.0095

C-T off	543.295	1	543.295	13.381	0.0146
D-V	954.835	1	954.835	23.517	0.0046
AB	24.641	1	24.641	0.606	0.4712
AC	6.755	1	6.755	0.166	0.7002
AD	40.488	1	40.488	0.997	0.3638
BC	25.287	1	25.287	0.622	0.4657
BD	59.913	1	59.913	1.475	0.2786
CD	4.3365	1	4.336	0.106	0.757
Residual	203.008	5	40.601		
Cor Total	8594.736	15			

3.2 Analysis of TWR

In this case also ANOVA was carried out to identify significant parameter on the TWR. The ANOVA for the TWR was carried out at confidence level of 95%. Then the responses which are having p value less than the 0.05 are said to be significant.

From the Table 3, we can say that Current and voltage are significant effective on the material removal rate because the P value of T on is 0.0450. There is no significant effect of Current, T off and voltage on tool wear rate.

Table 3. ANOVA table for TWR

Source	S S	df	M S	f-value	p-va;ue
Model	2.15E-03	10	2.15E-04	5.1	0.043
A-I	1.52E-04	1	1.52E-04	3.6	0.1163
B-T on	2.66E-06	1	2.66E-04	6.31	0.0536
C-T off	5.99E-06	1	5.99E-06	0.14	0.7216
D-V	8.46E-05	1	8.46E-05	2.01	0.2155
AB	2.15E-04	1	2.15E-04	5.12	0.0732
AC	4.06E-06	1	4.06E-06	0.096	0.7688
AD	1.58E-07	1	1.58E-07	3.76E-03	0.9535
BC	2.19E-05	1	2.19E-05	0.52	0.5031
BD	1.32E-05	1	1.32E-05	0.31	0.5996
CD	8.42E-07	1	8.42E-07	0.02	0.893
Residual	2.11E-04	5	4.21E-05		
Cor Total	2.36E-03	15			

3.2 Analysis of TWR

In this case also ANOVA was carried out to identify significant parameter on the surface roughness. The ANOVA for the surface roughness was carried out at confidence level of 95%. Then the responses which are having p value less than the 0.05 are said to be significant.

From the Table 4, we can say that Ton has significant effective on the surface roughness because the P value of T on is 0.0381. There is no significant effect of Current, T off and voltage on the surface roughness.

Table 4. ANOVA for surface roughness

source	Sum of squares	df	Mean square	F value	P-value

Model	13.20	4	3.30	0.58	0.0246
A-I	1.46	1	1.46	0.26	0.6232
B-T on	5.48	1	5.48	0.96	0.0381
C-T off	2.93	1	2.93	0.51	0.4884
D-V	1.37	1	1.37	0.24	0.6335
Residual	62.78	11	5.71		
Cor Total	75.98	15			

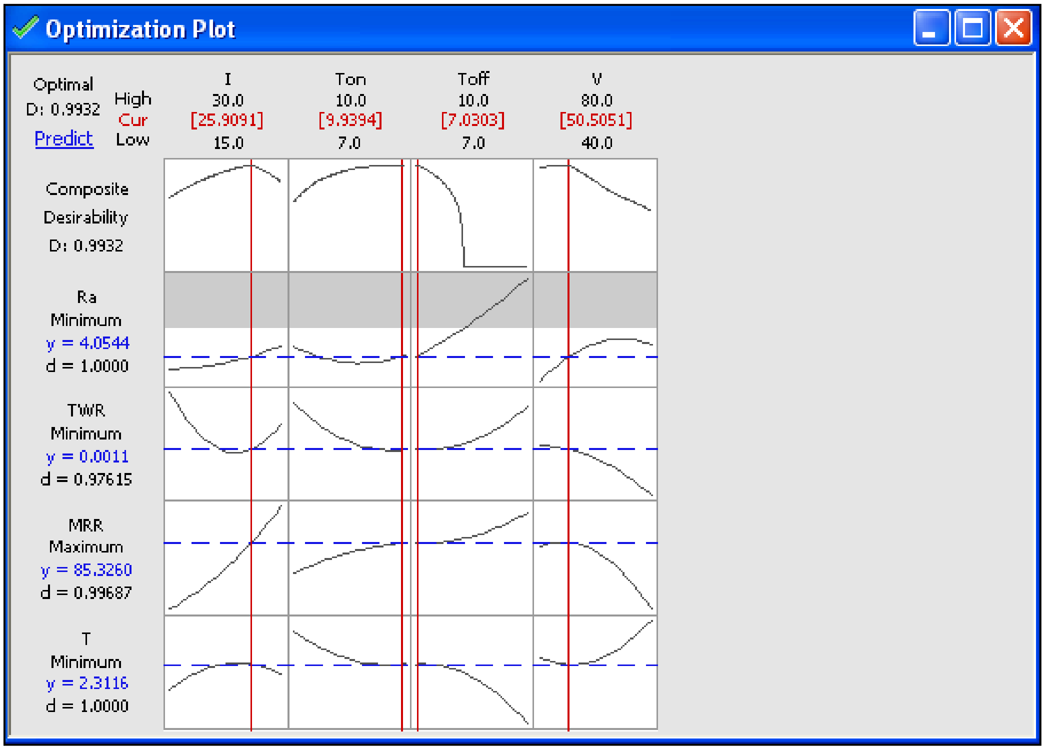
IV. MULTI RESPONSE OPTIMIZATION

In the present work,multi responses optimization was used to optimize process parameters for minimum surface roughness,tool wear rate and maximum metal removal rate.

In this optimization plot of response methodology we have found the optimized values for the material removal rate ,tool wear rate and also time dependent for process of operation .here we got composite desirability D=0.9920 and also independent values tool wear rate =0.97628 and material removable rate =1.we consider the optimization are in red colour of indicating for response of function.

Finally for the multi response optimization of copper electrode and INCONEL 825 parameters these are as follows.

Current =30 amperage
Ton=10 milli second
Toff= 7 milli second
Voltage=69volts



Optimal
D: 0.9932

	I	Ton	Toff	V
High	30.0	10.0	10.0	80.0
Cur	[25.9091]	[9.9394]	[7.0303]	[50.5051]
Low	15.0	7.0	7.0	40.0

Composite
Desirability
D: 0.9932

Ra
Minimum
y = 4.0544
d = 1.0000

TWR
Minimum
y = 0.0011
d = 0.97615

MRR
Maximum
y = 85.3260
d = 0.99687

T
Minimum
y = 2.3116
d = 1.0000

V. CONCLUSIONS

The optimization of process parameters namely discharge current, pulse on time, pulse off time and voltage can be done by using RSM for eroding of HSS and Inconel 825. The conclusion are drawn from this work is as fallow.

- The empirical relationship was developed for material removal rate, tool wear rate and surface roughness on EDM with eroding parameter
- ANOVA was used to identify significant parameters on the out variables.in ANOVA for material removal rate all process parameter were found to be significant.in ANOVA for tool wear rate was found to be significant.
- The RSM was used for multi response optimization of process parameters. Current of 30amp, pulse on time of 10ms, pulse off time of 7ms and voltage of 69 volts are optimum erosion parameters.

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