PARAMETRIC STUDY OF INCOLOY 800® (SUPER ALLOY) IN DRY-EDM

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ABSTRACT

EDM (Electro Discharge Machining) is mainly used to machine difficult-to-machine materials, high strength temperature resistant alloys and complex geometries. Incoloy 800 is a Nickel based super alloy which is one of the hard materials difficult to machine traditionally hence it is machined by advanced manufacturing technology like EDM. In this study Incoloy 800® is machined by Dry EDM. Air and oxygen are used as dry dielectric medium. In the present study effort has been made to study the effect of process parameters viz. peak current, duty cycle and pulse on time on Incoloy 800®. Design of Experiments has been done by using Taguchi L9 orthogonal Array. The parameters have been compared with die sinking EDM using kerosene as dielectric. The response parameters selected for study are Material Removal Rate (MRR), Tool Wear Rate (TWR) and Surface Roughness (Ra). The parameters are analysed by ANOVA.

Keywords: ANOVA, Dry EDM, Incoloy 800, Super alloy, Taguchi Design

I. INTRODUCTION

Electrical discharge machining (EDM) is a non traditional machining process. that uses electrical spark discharge to machine electrically conducting materials, geometrically complex shapes or hard material components that are precise and difficult to machine using a more traditional approach such as heat treated tool steels, composites, super alloys, ceramics, carbides, heat resistant steels etc. being widely used in die and mould making industries, aerospace, aeronautics and nuclear industries. Dielectric fluid should have enough strong dielectric resistance so that it does not breakdown electrically too easily but at the same time ionize when electrons collide with its molecule. Moreover, during sparking it should be thermally resistant as well. It helps in initiating discharge by serving as a conducting medium when ionised, and conveys the spark. It concentrates the energy to a very narrow region, helps in quenching the spark, cooling the work, tool electrode and enables arcing to be prevented, carries away the eroded metal along with it. So generally Kerosene, oil, deionised water are used as very common type of liquid dielectric fluid. EDM generally uses kerosene as a dielectric fluid which has some disadvantages like it is not environment friendly and pollute atmosphere and dangerous to health, inflammable also and it is costly. There are eco friendly alternatives dielectric fluids available like different gases viz. oxygen, nitrogen, air etc.

II. LITERATURE REVIEW

Different variants of Elecro Discharge Machining were tried out like powder mixed dielectric fluid[1], rotary electrode[2], Ultrasonic movement of work piece or tool by transducer[3], Micro EDM[4] etc. to improve the machinability and efficiency of the process. The other aspect of the process is to improve the machinability by making it environment friendly. Grzegorz Skrabalak & Jerzy Kozak [5] have presented results of simulation and mathematical modelling of the material removal rate of electro discharge milling process with compressed air as dielectric, C.C. Kao, Jia Tao, Albert J. Shih [6] investigated the near dry electrical discharge machining (EDM) process. Near dry EDM uses liquid gas mixture as the two phase dielectric fluid and compare the results of Dry EDM (Oxygen is used as dielectric fluid), near Dry EDM and Die sinking EDM. They got very low MRR but got improved surface finish by Pressurised oxygen as dielectric. C.C. Kao, Jia Tao, Albert J. Shih [6] have also got mirror like surface finish in Dry EDM with low MRR. So it is one of the most advantages of Dry EDM. Also Dry EDM has some advantages like it is totally environment friendly (there is no pollution), air is totally free of cost so eco friendly, non inflammable etc.

III. DESIGN OF EXPERIMENTS

The selected process control parameters for experimentation are pulse on time, duty cycle and peak current. Design of experiments has been done by Taguchi L9 orthogonal array. The levels of the individual process parameters/factors are given in Table 1.

Table 1: Process Parameters and their Levels

Factors	Parameters	Levels		
		L1	L2	L3
A	Pulse on Time	17	48	62
B	Duty cycle	0.42	0.49	0.56
C	Peak current	36	43	50

Total 27 experiments were conducted using Taguchi experimental design methodology, considering nine experiments using three different dielectric medium. The selected response parameters for the study are material removal rate, tool wear rate and surface roughness.

IV. EXPERIMENTAL DETAILS

Experiments were performed on JOEMARS AZ-50 Die sinking EDM machine. Experiments were done on Incoloy 800® with three types of dielectric medium (1) Oxygen, (2) Air, (3) Kerosene and effect of input parameter on responses have been compared . Incoloy -800® a nickel based super alloy material having diameter 14 mm and thickness 3 mm has been used as a work piece material and Electrode grade copper is selected as a tool material. For the experimental work tubular Copper electrode is used having outer diameter of 10 mm and inside diameter is 3.4 mm.

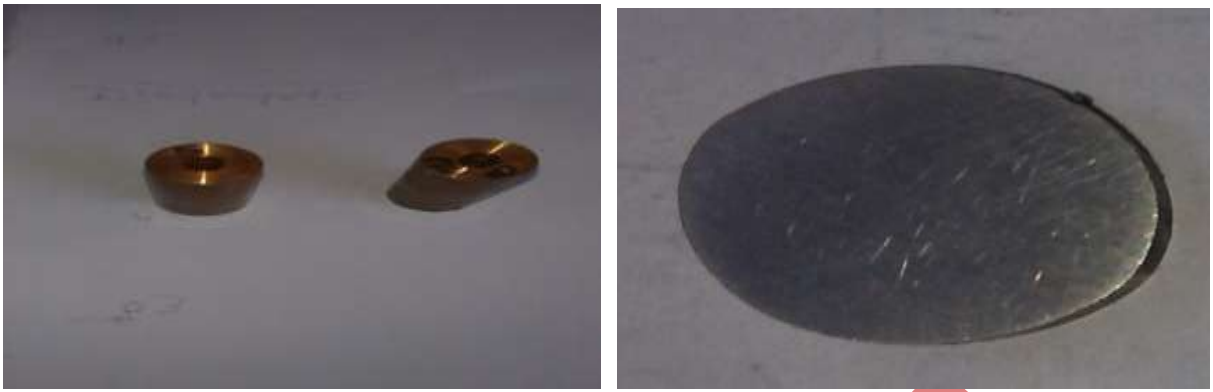

Fig. 1: Tool material and Incoloy -800® work piece

Experimental setup is shown in Fig.2 and Fig.3. Provision of pressurized air for dry EDM setup has been accomplished by supplying air from compressor to the nozzle of EDM to replace liquid dielectric line by pressurized air line as shown in Fig.2.

Fig. 2: Dry EDM setup for air as dielectric fluid

Fig. 3: Dry EDM setup for Oxygen as dielectric fluid

However, in preliminary trials it was found that by using solid electrode, machining was not stable. Even the impression of tool not obtained. This is due to poor flushing in centre of work piece copper electrode material was deposited on it. After using hollow electrode, machining was better because hollow electrode facilitates good central flushing which facilitates the machining conditions. All hollow electrodes were polished up to 0.1micron.

Fig. 4: Machining impression with Solid electrode and Tubular Electrode

If proper flushing does not occurs then electrode material and debris start deposited on work piece which stops further machining. Same way if duty cycle is less than 40%, MRR is low because of energy discharge is less causes problem of copper deposition. Flushing pressure is also one of the major parameter for controlled machining conditions. It was found that flushing pressure less than 5 bars pause the machining further.

Fig. 5: Machining impression on Incoloy 800® by using dielectric as (a) oxygen (b) air and (c) kerosene

V. RESULTS & DISCUSSIONS

The analysis of variance (ANOVA) is being carried out to identify the significant variables and to quantify their effects on the response characteristics. In the present study all analysis has been carried out using Minitab 15 software.

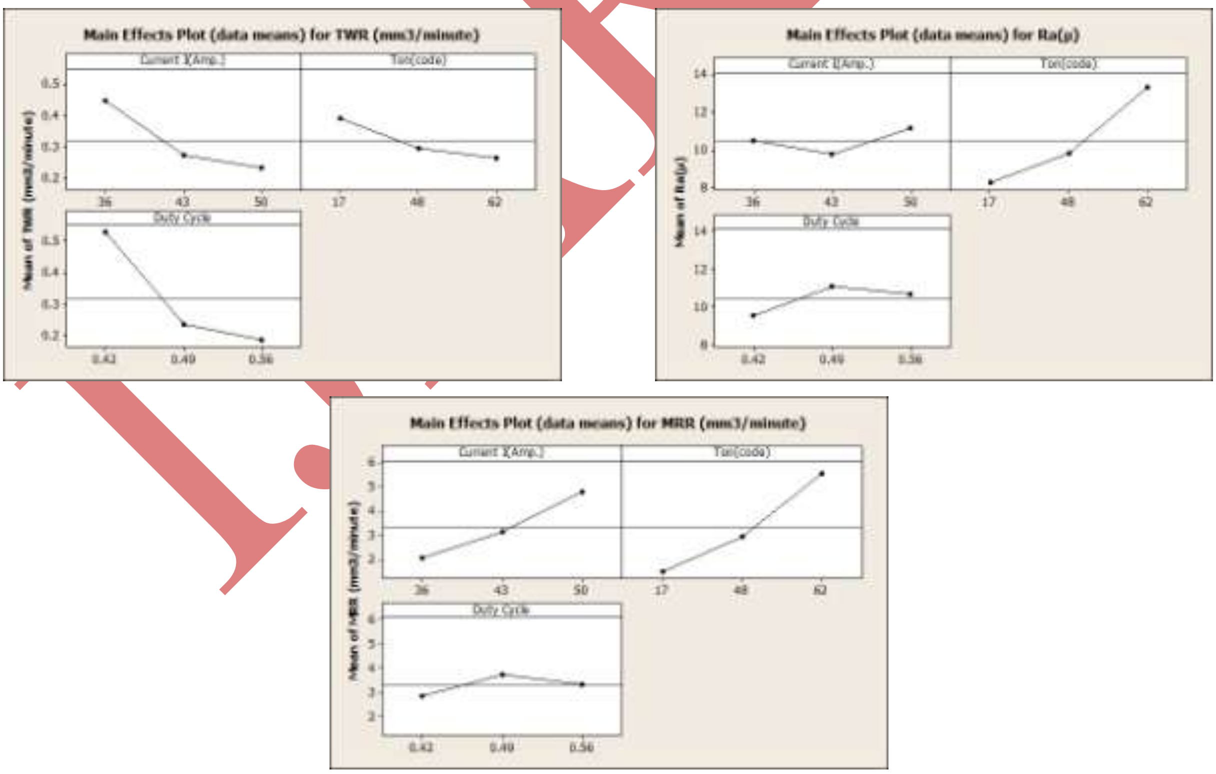

Fig. 6: Effect of process parameters on Response parameters when Oxygen is used as dielectric

Table 2: ANOVA for Oxygen used as Dielectric

ANOVA for MRR						
Source	**DF**	**Seq SS**	**Adj SS**	**Adj MS**	**F**	**P**
Current I(Amp.)	2	11.24	11.24	5.62	4.3	0.189
Ton(code)	2	25.141	25.141	12.57	9.62	0.094
Duty Cycle	2	1.234	1.234	0.617	0.47	0.679
Error	2	2.613	2.613	1.307		
Total	8	40.228				
S = 1.14313 R-Sq = 93.50% R-Sq (adj) = 74.01%						
ANOVA for TWR						
Current I(Amp.)	2	0.0770	0.0770	0.0385	5.5	0.154
Ton(code)	2	0.0261	0.0261	0.0130	1.87	0.349
Duty Cycle	2	0.2084	0.2084	0.1042	14.9	**0.063**
Error	2	0.0139	0.0139	0.0069		
Total	8	0.3255				
S = 0.0836437 R-Sq = 95.70% R-Sq (adj) = 82.81						
ANOVA for Surface Roughness						
Current I(Amp.)	2	3.0178	3.0178	1.5089	15.22	**0.062**
Ton(code)	2	39.8061	39.8061	19.903	200.8	**0.005**
Duty Cycle	2	3.8493	3.8493	1.9247	19.42	**0.049**
Error	2	0.1982	0.1982	0.0991		
Total	8	46.8714				
S = 0.314831 R-Sq = 99.58% R-Sq (adj) = 98.31%						

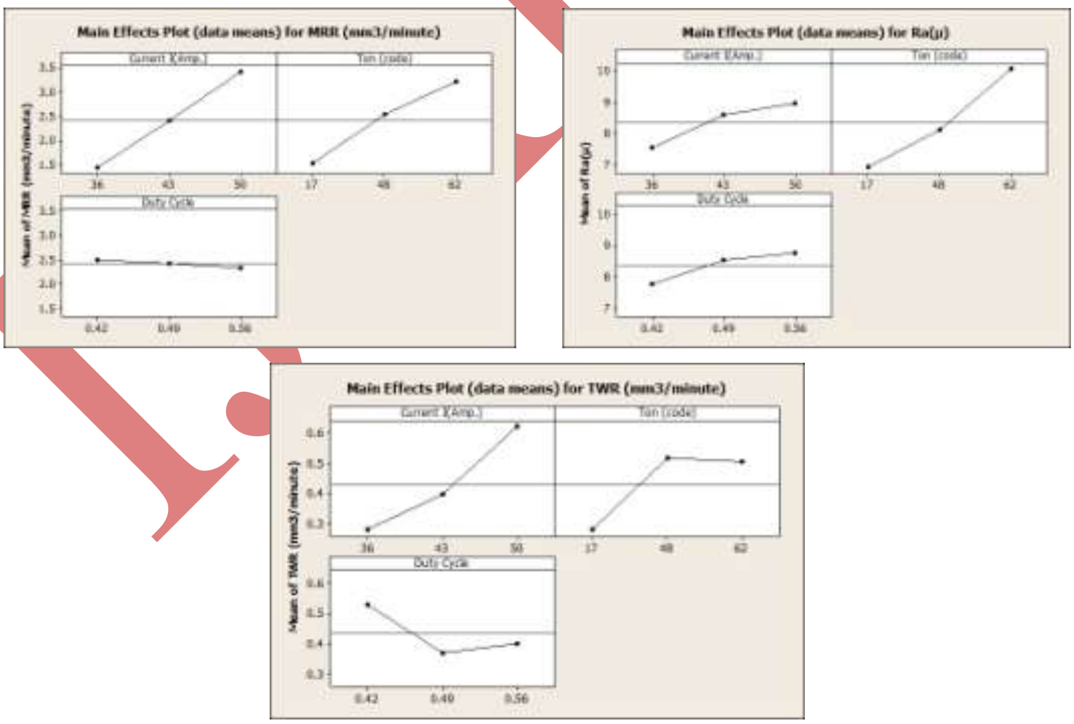

Fig. 7: Effect of Process parameters on Response parameters when Air used as dielectric

Table 3: ANOVA for Air used as Dielectric

ANOVA for MRR						
Source	**DF**	**Seq SS**	**Adj SS**	**Adj MS**	**F**	**P**
Current I(Amp.)	2	5.7929	5.7929	2.8964	9.43	0.096
Ton(code)	2	4.3332	4.3332	2.1666	7.06	0.124
Duty Cycle	2	0.0417	0.0417	0.0209	0.07	0.936
Error	2	0.6142	0.6142	0.3071		
Total	8	10.782				
S = 0.554159 R-Sq = 94.30% R-Sq (adj) = 77.21%						
ANOVA for TWR						
Current I(Amp.)	2	0.1783	0.1783	0.0891	11.08	0.083
Ton(code)	2	0.1073	0.1073	0.0536	6.67	0.13
Duty Cycle	2	0.0432	0.0432	0.0216	2.69	0.271
Error	2	0.0161	0.0161	0.0080		
Total	8	0.3450				
S = 0.0897205 R-Sq = 95.33% R-Sq(adj) = 81.33%						
ANOVA for Surface Roughness						
Current I(Amp.)	2	3.2342	3.2342	1.6171	19.45	**0.049**
Ton(code)	2	15.2375	15.2375	7.6188	91.62	**0.011**
Duty Cycle	2	1.5886	1.5886	0.7943	9.55	0.095
Error	2	0.1663	0.1663	0.0832		
Total	8	20.2267				
S = 0.288370 R-Sq = 99.18% R-Sq(adj) = 96.71%						

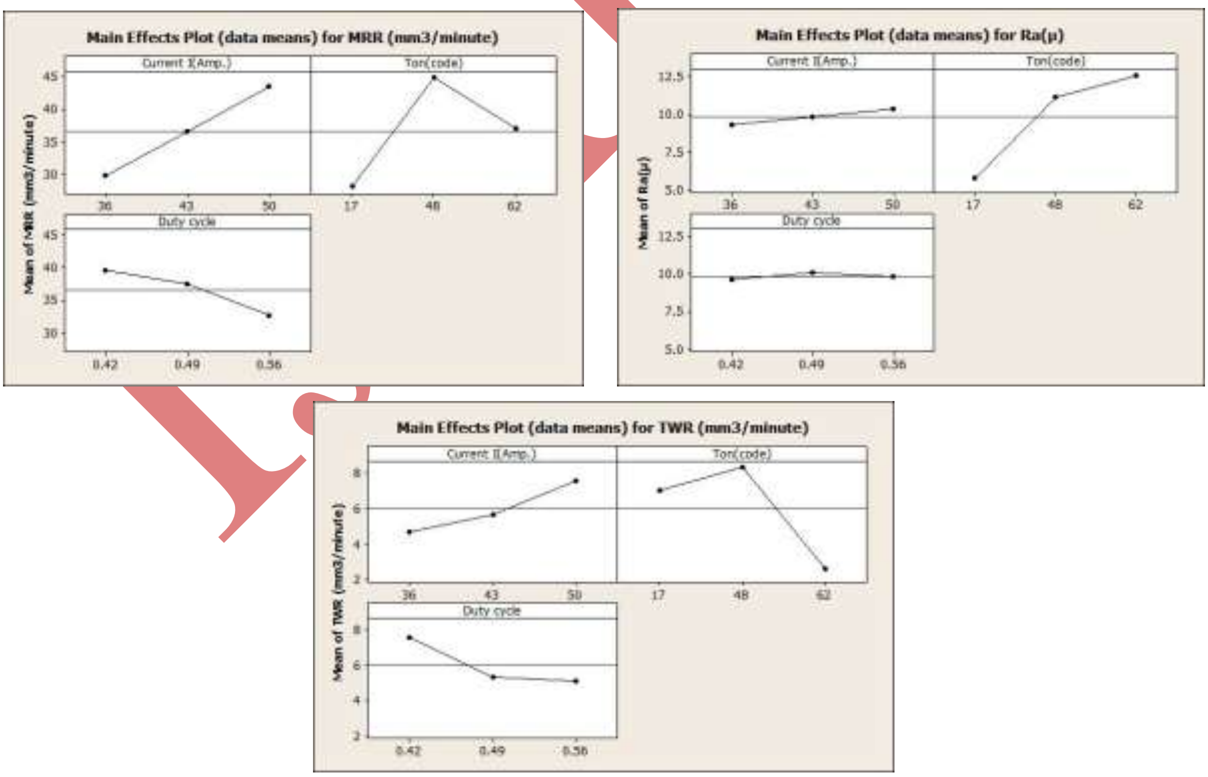

Fig. 8: Effect of process parameters on Response parameters when Kerosene is used as dielectric

Table 4: ANOVA for Kerosene used as Dielectric

ANOVA for MRR						
Source	**DF**	**Seq SS**	**Adj SS**	**Adj MS**	**F**	**P**
Current I(Amp.)	2	283.94	283.94	141.97	3.07	0.245
Ton(code)	2	419.49	419.49	209.75	4.54	0.18
Duty Cycle	2	75.93	75.93	37.97	0.82	0.549
Error	2	92.36	92.36	46.18		
Total	8	871.72				
S = 6.79543 R-Sq = 89.41% R-Sq (adj) = 57.62%						
ANOVA for TWR						
Current I(Amp.)	2	13.018	13.018	6.509	1.2	0.455
Ton(code)	2	53.963	53.963	26.981	4.97	0.168
Duty Cycle	2	11.125	11.125	5.563	1.02	0.494
Error	2	10.867	10.867	5.434		
Total	8	88.973				
S = 2.33103 R-Sq = 87.79% R-Sq (adj) = 51.14%						
ANOVA for Surface Roughness						
Current I(Amp.)	2	1.604	1.604	0.802	2.72	0.269
Ton(code)	2	76.489	76.489	38.244	129.48	**0.008**
Duty Cycle	2	0.318	0.318	0.159	0.54	0.65
Error	2	0.591	0.591	0.295		
Total	8	79.001				
S = 0.543469 R-Sq = 99.25% R-Sq(adj) = 97.01%						

In the above figures (6, 7 and 8) we can show that MRR increases with the increase of pulse on time and peak current. This is because the discharge energy increases with the pulse on time and peak current leading to a faster MRR. Duty cycle is inversely proportional to pulse off time & directly proportional to pulse on time. As the pulse off time decreases, duty cycle increase, the number of discharges within a given period becomes more which leads to increase MRR.

From the ANOVA tables we can see Most of input parameters are significantly affect on surface roughness only.

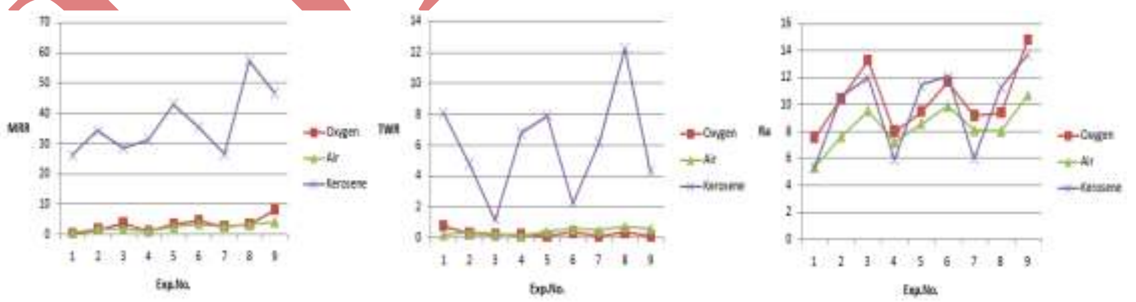

Fig. 9: Comparison of MRR, TWR and Surface roughness for oxygen, air and kerosene as dielectric

Fig. 9 depicts the comparison of response parameters with respect to each experiment carried out by using same process parameters and different dielectric medium viz. oxygen, air and kerosene.

VI. CONCLUSION

1. All response parameters are almost same for dry EDM (oxygen and air) but there is apparent difference for EDM using kerosene as dielectric.
2. It is observed that MRR is more for EDM using kerosene as dielectric as compare to dry EDM (oxygen and air)
3. TWR is very low for dry EDM (oxygen and air) as compare to EDM using kerosene as dielectric.
4. Surface finish is good for dry EDM (oxygen and air) as compare to EDM using kerosene as dielectric and it is in range of 6 to 13 micron.
5. It is observed from ANOVA that peak current and pulse on time are most significant parameters for all response parameters included in the study
6. As the peak current increases MRR also increases with increase in surface roughness.
7. With increase in pressure in dry EDM MRR increases with increase in surface roughness.
8. Reason behind low MRR in dry EDM is lack of proper flushing.

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