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An Experimental investigation of different electrode on INCONEL718 using EDM

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Abstract ***—Electro Discharge Machining (EDM) is an electro-thermal non-traditional machining Process, EDM is mainly used to machine difficult-to-machine materials and high strength temperature resistant alloys. Electrical discharge machining performance is mainly find out on the basis of Material Removal Rate (MRR), Tool Wear Rate (TWR) and Surface Roughness (SR). The important EDM machining parameters affecting on the performance parameters are Discharge current, pulse on time, pulse off time, voltage, arc gap, flashing pressure and duty cycle. The Workpiece material selected in this work is INCONEL718 is a High Strength, Temperature Resistant (HSTR) Nickel based super alloy. The tool material are Aluminium, Copper and Brass. The input variable parameters are current, pulse on time and pulse off time. Taguchi Method is applied to create an L9 orthogonal array of input variables and ANOVA is used to optimize the parameters using MINITAB 17 software.***

Keywords- EDM, TWR, SR, DOE, ANOVA, TAGUCHI method.

I. INTRODUCTION

Electric Discharge Machining (EDM) is a nontraditional machining process in the sense that they do not employ traditional tools for metal removal and instead directly by means of electric spark erosion [1].Electro Discharge Machining (EDM) is an electro-thermal non-traditional machining Process, where electrical energy is used to generate electrical spark and material removal mainly occurs due to thermal energy of the spark. EDM is mainly used to machine difficult-to-machine materials and high strength temperature resistant alloys. The non-contact machining technique has been continuously evolving from a mere tool and dies making process to a micro-scale application machining alternative attracting a significant amount of research interests. EDM is especially well-suited for cutting intricate contours or delicate cavities that would be difficult to produce with a grinder, an end mill or other cutting tools. EDM is a thermoelectric process in which heat energy of spark is used to remove material from the workpiece [2].The workpiece and the tool should be made of electrically conductive material. A spark is produced between the two electrodes (tool and workpiece) and its location is determined by the narrowest gap between the two. Duration of each spark is very short. The entire cycle time is usually few micro-seconds (μs). The frequency of sparking may be as high as thousands of sparks per second. The area over which a spark is effective is also very small. Temperature of the area under the spark is very high. As a result, the spark energy is capable of partly melting and partly vaporizing material from the localized area on both the electrodes, i.e. the workpiece and tool. The material is removed in the form of craters, which spread over the entire surface of the workpiece [2]. Chinmaya P Mohanty et al. (2014) [3] evaluate that MRR value increases monotonically with increase in current with graphite and copper electrodes but increases slowly with the use of brass electrode. Material removal is higher, while machining with graphite electrode followed by copper and brass respectively. M Manohar et al. (2014)) [4] Observed that the bottom surface profile of the electrode was contributing towards many aspects like Material Removal Rate (MRR), Electrode Wear Rate (EWR), surface roughness and surface integrity. Electrodes having Convex, Concave and Flat profile at their bottom surface were chosen for the experimental study**.** They conclude from this paper that electrodes of convex bottom profile perform better than flat or concave profiled electrodes. Sengottuvel.P et al. (2013) [5] The objective of the present work was to investigate the effects of various EDM input parameters as well as the influence of different tool geometry on Material Removal Rate(MRR), Tool Wear Rate(TWR) and Surface Roughness(SR) on machining of Inconel 718 material by using copper electrode. Tool geometry of the electrodes was circle (C), square (S), rectangle (R) and triangle (T). Rectangular tool geometry was best for copper electrode. R. Manikandan et al. (2012) [6] the study focuses on a specific combination of electrode and work piece material and proposes a typical method for micro EDM process optimization. The cutting of the Inconel 718 using Micro EDM with a brass electrode by using Taguchi methodology has been reported. It found that these parameters have a significant influence on the machining characteristics such as Metal Removal Rate (MRR), Overcut and Tool wear ratio. D Sudhakara et al. (2012) [7] in this project report parameters such as peak current, pulse on time, duty factor were chosen to study the machining characteristics. They conclude that when current increases, the MRR also increases. When the current is increased, surface roughness is also increased. S Ahmad et al. (2013) [8]] in this study peak current, I are selected as the most important electrical pulse parameters. For surface roughness, lowest peak current and the lowest pulse duration is suggested in order to achieve good surface finish.

II. EXPERIMENTAL SETUP

The electric discharge machine, model SPARKONIX SN-25 (die-sinking type) with servo-head (constant gap) and positive polarity for electrode was used to conduct the experiments. Spark Erosion EDM oil was used as dielectric fluid.
Material to be used as workpiece- INCONEL718
Electrode to be used- Copper, Alluminium, Brass all of have 10.00 mm diameter.
Variable Input Parameters- Current, Pulse on time, Pulse off time.

Constant Input Parameter- Voltage [50 V], Flushing Pressure [0.5 lb/m2]
Depth of Cut- 2 mm
Rectangular work piece has to be machined with each side of 17 mm Thickness.
Experiment has to be done at L.D.R.P-ITR, Gandhinagar.
DOE Adopted: Taguchi L9 Orthogonal Array, ANOVA

Table 1: Mechanical properties of Inconel 718 material

Density (g/cm3)	Melting Point(^{0}C)	Co-Efficient Expansion (µm/m ^{0}C)	Modulus of Rigidity (kN/mm2)	Modulus of Elasticity (kN/mm2)	Tensile Strength (N/mm2)	Hardness Rockwell B	Elongation %
8.19	1336	13	77.2	204.9	1240	100	45

Table 2: The Chemical Composition of Inconel 718

Alloying Element	Ni	Cr	Fe	Mo	Nb (+Ta)	Co	Mn
% by mass	50 – 55	17 - 21	Balance	2.8 -3.3	4.75 - 5.5	1	0.35
Alloying Element	Al	Ti	Si	C	S	P	B
% by mass	0.2-0.8	0.65-1.15	0.35	0.08	0.015	0.015	0.006

INCONEL718 is used in the field of gas turbine components, cryogenic storage tanks, jet engines, pump bodies and parts, rocket motors, thrust reversers, nuclear fuel element spacers, manufacturing of dies and moulds in manufacturing industries, components in aerospace and automotive industries.
Technical reason for selecting Copper (commercial): Copper is a tough, ductile and malleable material. Excellent heat conductivity, excellent electrical conductivity, good corrosion resistance. The melting point for pure Copper is 1083ºC. The conductivity of Copper is 97% that of silver. Due to its much lower cost.
Technical reason for selecting Alluminium (6351 T6): The melting point for Alluminium 6351 T6 is 596ºC. The aluminum 6351 alloy is used in manufacturing tubes and pipes. Aluminum alloys tend to lose their strength when they are exposed to temperatures of about 200-250°C. However, their strength increases at subzero temperatures. They have high corrosion resistance.
Technical reason for selecting Brass (BSS 249): Brass is an alloy of copper and zinc; the proportions of zinc and copper. Brass has excellent thermal conductivity. Brasses can also have high corrosion resistance and high tensile strength. Resistance against corrosion, great conductivity, waterproof properties, excellent brazing and soldering properties, wieldable.

Design of experiment approach (DOE), ANOVA and Taguchi method were used to analyze cutting parameters with consideration of workpiece surface roughness and identify the optimized parameter regions. The L9 Orthogonal Array methodology has been used to plan the experiments. Three factors are chosen the design becomes a 3 level 3 factorial Taguchi design. The version 17 of the MINITAB software was used to develop the experimental plan for L9 Orthogonal Array. The values of the parameters that have varied during the execution of experiments are shown in Table 3.

Table 3 EDM variables and their levels

Symbol	Input Parameters	Level 1	Level 2	Level 3
A	Current (Amp.)	5	10	15
B	Pulse on Time (µs)	5	6	7
C	Pulse off Time (µs)	4	5	6

III. ANALYSIS AND DISCUSSION OF EXPERIMENTAL RESULT

The effect of process parameters on the machining parameter is recorded in the table. The nine experiments done on the electro discharge machine based on the Taguchi method and summarized in the following table 4.

Table 4. Design Layout and Experimental Results

PR. No.	Current (A)	Pulse on Time	Pulse off Time	Material Removal Rate (mm3/min) Copper	Material Removal Rate (mm3/min) Alluminium	Material Removal Rate (mm3/min) Brass
				MRR	MRR	MRR
1	5	5	4	3.97	2.0175	2.2994
2	5	6	5	3.91	3.2234	2.1468
3	5	7	6	3.62	4.3489	1.8746
4	10	5	4	16.75	6.1253	2.7454
5	10	6	5	15.93	6.3539	2.6029
6	10	7	6	15.28	6.8665	2.4805
7	15	5	4	26.56	7.092	2.4212
8	15	6	5	26.04	8.8527	2.0478
9	15	7	6	25.67	10.5889	1.5743

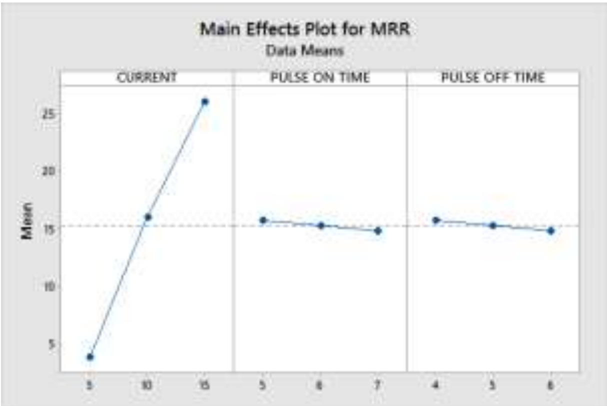

Fig 1. Main effect of process parameters on MRR

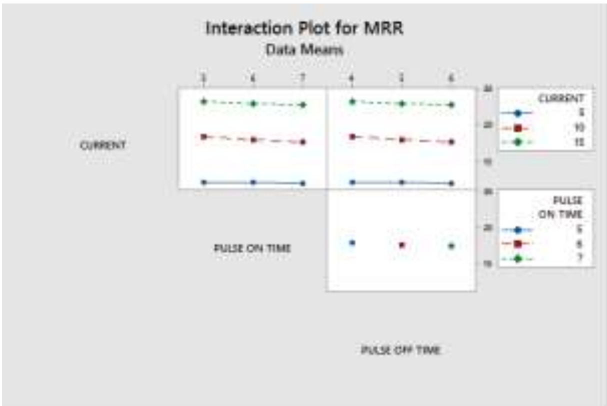

Fig 2. Interaction effect of process parameters on MRR

Fig 1 shows the main effect plot of process parameters on Material removal rate (MRR) at different parameters like current, pulse on time, and pulse off time in EDM process of machining for INCONEL718 by Copper tool. From the fig, it can be seen that:-
Effect of Current: Material removal rate is increase with the increase in Current.
Effect of Pulse on Time: Material removal rate is slight decrease with the increase in Pulse on Time.
Effect of Pulse off Time: Material removal rate is a slight decrease with the increase in Pulse off Time.
Fig 2 shows the interaction effect plot of process parameters on Material removal rate at different parameters like current, pulse on time, and pulse off time in EDM process of machining for INCONEL718 by Copper tool.

Fig 3 shows the main effect plot of process parameters on Material removal rate (MRR) at different parameters like current, pulse on time, and pulse off time in EDM process of machining for INCONEL718 by Alluminium tool. From the fig, it can be seen that:-
Effect of Current: Material removal rate is increase with the increase in Current.

Effect of Pulse on Time: Material removal rate is increase with the increase in Pulse on Time.
Effect of Pulse off Time: Material removal rate is a slight decrease with the increase in Pulse off Time.
Fig 4 shows the interaction effect plot of process parameters on Material removal rate at different parameters like current, pulse on time, and pulse off time in EDM process of machining for INCONEL718 by Alluminium tool.

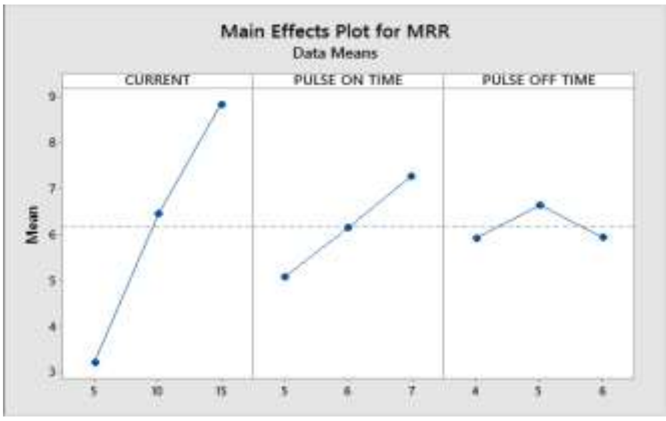

Fig 3. Main effect of process parameters on MRR

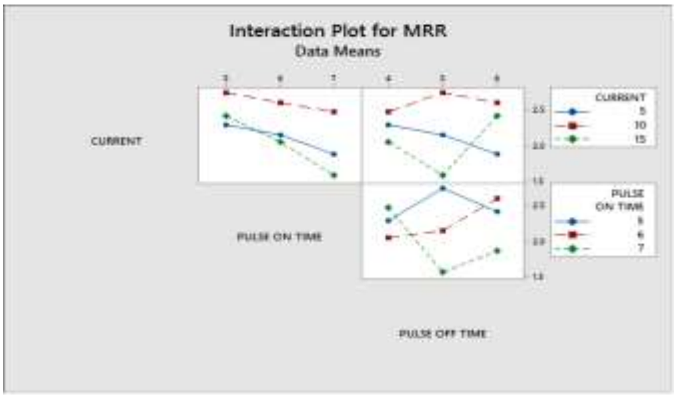

Fig 4. Interaction effect of process parameters on MRR

Fig 5. Main effect of process parameters on MRR

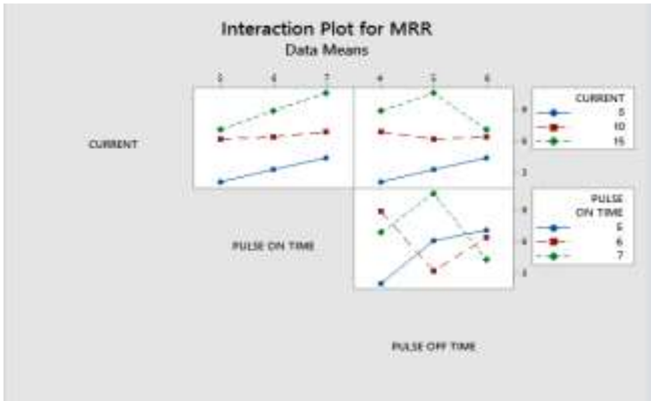

Fig 6. Interaction effect of process parameters on MRR

Fig 5 shows the main effect plot of process parameters on Material removal rate (MRR) at different parameters like current, pulse on time, and pulse off time in EDM process of machining for INCONEL718 by Brass tool. From the fig, it can be seen that:-
Effect of Current: Material removal rate is increase with the increase in Current.
Effect of Pulse on Time: Material removal rate is increase with the increase in Pulse on Time.
Effect of Pulse off Time: Material removal rate is a slight decrease with the increase in Pulse off Time.
Fig 6 shows the interaction effect plot of process parameters on Material removal rate at different parameters like current, pulse on time, and pulse off time in EDM process of machining for INCONEL718 by Brass tool.

IV. CONCLUSION

Effect of process parameters on Material Removal Rate for Copper tool was concluded as under:

- Effect of Current: Material removal rate is increase with the increase in Current.
- Effect of Pulse on Time: Material removal rate is slight decrease with the increase in Pulse on Time.
- Effect of Pulse off Time: Material removal rate is a slight decrease with the increase in Pulse off Time.

Effect of process parameters on Material Removal Rate for Alluminium tool was concluded as under :

- Effect of Current: Material removal rate is increase with the increase in Current.
- Effect of Pulse on Time: Material removal rate is increase with the increase in Pulse on Time.
- Effect of Pulse off Time: Material removal rate is a slight decrease with the increase in Pulse off Time.

Effect of process parameters on Material Removal Rate for Brass tool was concluded as under :

- Effect of Current: Material removal rate is decrease with the increase in Current.
- Effect of Pulse on Time: Material removal rate is decrease with the increase in Pulse on Time.
- Effect of Pulse off Time: Material removal rate is a increase with the increase in Pulse off Time.

Finally it is found that the copper tool is more suitable for cutting operation. If current increase MRR is increase. If increase in current surface roughness is also increase. Pulse on time increase MRR increase for Copper and Alluminium Tool and for Brass tool current increase MRR decrease.

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