EXPERIMENTAL INVESTIGATION OF VARIOUS PROCESS PARAMETERS OF MICRO WEDM ON INCONEL-601

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Abstract: Electrical Discharge Machining (EDM) process is one of the most popular advanced manufacturing process in which machining occurs in non-contact type. In EDM, work piece material is removed by continuous sparks between work piece and electrode. Wire EDM is the widely used machining process for manufacturing of complex shapes. This study involves the effects of process parameters of micro WEDM on Material Removal Rate (MRR) and surface roughness of Inconel-601. Inconel-601 is widely used material due to its various characteristics and is difficult to machine using conventional machining processes.

Key Words- EDM, WEDM, INconel-601, MRR, Surface roughness.

I. INTRODUCTION

Electrical Discharge Machining process is one of the most popular advanced manufacturing process in which machining occurs in non-contact type. In EDM, removal of material takes place through spark erosion. A continuous series of electric spark between the work piece and the electrode creates a higher temperature which ultimately causes erosion of the work piece in machining zone. The EDM is an advance machining process in which machining of a material can be done which can conduct electricity, irrespective of its mechanical properties such as hardness. Electro Discharge Machining (EDM) is an electric-thermal non-conventional machining process, where electrical energy is used to generate an electrical spark and material removal takes place due to the thermal energy of the spark. Wire EDM (WEDM) is the advancement of EDM process in which wire is used as tool for machining of work piece. A continuous feed of wire which is connected to positive terminal is done to erode the work piece material which is connected to the negative terminal. In WEDM, the metal-removal process is done by applying a pulse (ON/OFF) electrical discharge of high-frequency current from electrode to work piece. This removes (erodes) small pieces (debris) of metal from the work piece at a controlled rate. Dielectric fluid acts as a separating medium between work piece and tool. It also acts as a coolant and for flushing away the debris. WEDM meets the requirements of tool making and machining sector. WEDM is an important machining process which produces complicated cuts on difficult to machine metals without using high cost grinding or cutting tools [1].Inconel-601 is a widely used Nickel-Chromium super alloy. The composition of Inconel-601 is Nickel 61%, Chromium 23%, Aluminum 1.4%, Manganese 1%, Silicon 1%, Carbon 0.1% and Sulphur 0.015%. The melting point of Inconel-601 is 1360-1411ºC. It has great resistance to heat and pressure. The equipment of electric power generation, gas turbine, industries of aerospace, chemical vessels working in high working temperature and nuclear reactors are made up of Inconel-601. Inconel-601 has high resistance to high temperature. It has very good mechanical strength and resistance to aqueous as well as chemical corrosion. When we go through a survey on researches done in EDM area, only 30% of the total researches are carried out in the WEDM region. Hence there is a need for more research's to be done in micro WEDM sector. The experimental investigation of the process parameters of micro WEDM on Inconel 601 is done in order to get better results for response parameters- Material removal rate (MRR) and Surface Roughness (SR).

II. LITERATURE SURVEY

Kumar et al. [1] studied and found that while machining of pure titanium, the pulse on time affected the most on MRR. When pulse off time increases the MRR decreases. The pulse on time, voltage and wire speed increased the crater diameter. [1]

Ho K. and Newman S. [2] concluded that WEDM is a well flourished machining process which meets the requirements of most of the machining industries. This process is widely being used for micromachining. Therefore there is need to take efforts in order to make the WEDM process more robust and economic.

Dabade and Karidkar [3] performed WEDM on Inconel 718 and studied the effect of pulse on time and input current on Material Removal Rate (MRR), Surface Roughness (SR), cutting width (Kerf) and found that pulse on time and input current were most affecting parameters for MRR.

Garg et al. [4] works on metal matrix composites which are advance materials with low weight and found WEDM is most suitable machining process for such materials.

Rao et al. [5] found that PoT and input current are most influencing parameters for WEDM. The maximum MRR was observed at input current 12A and PoT 110µsec.

Shandilya et al. [6] carried out the study of PoT, voltage, and wire feed rate on Kerf width in WEDM process on Aluminium 6061. They found that pulse on time and wire feed rate are most affecting input parameters in WEDM process.

Tilekar et al. [7] carried out WEDM process on mild steel and aluminium. The PoT was found to be most influencing parameter with confidence level of 98%.Input current with confidence level of 83% is affecting the Kerf width of mild steel.

Shyam Lal et al. [8] performed experiments to optimize the CNC WEDM with response variables surface roughness and Kerf width. The pulse on time and input current were found to be most affecting parameters.

Khan et al. [9] experimented and analyzed the WEDM process using Taguchi base grey relational analysis. On stainless steel (SS 304), for Kerf width and surface roughness PoT was found to be most influencing parameter.

From the literature survey, it is concluded that capacitance, voltage and pulse on time are the most influencing parameters for the WEDM process. The machine limitations and capabilities are also taken in to consideration while selecting the input as well as output variables for the dissertation work. Therefore, capacitance, voltage and pulse on time are selected as the input parameters and MRR, surface roughness and Kerf width are the response variables.

III. EXPERIMENTAL SETUP

For experimentation of WEDM on Inconel-601, the micro machining setup of synergy nano system is used. The enlarged view of micro WEDM setup is shown in Figure 1.

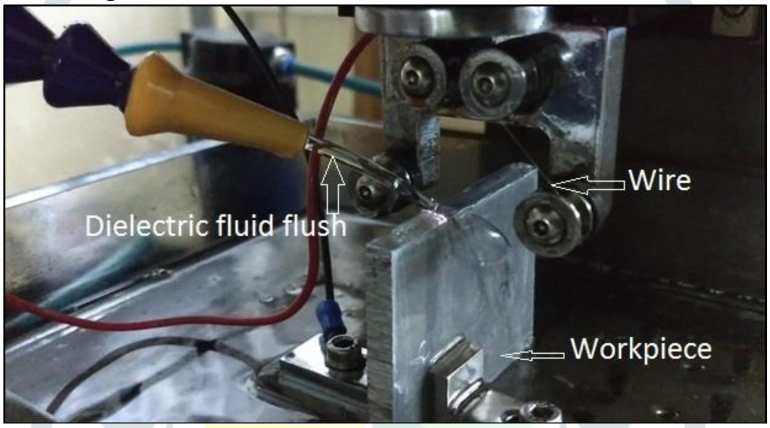


Fig-1: Experimental setup for micro Wire EDM

The surface roughness of the work piece after WEDM process is measured on Taylor Hobson surface roughness tester available. The Figure2 shows the Taylor Hobson surface roughness tester.

Fig-2: Taylor Hobson surface roughness tester.

Fig-3: Precise weighing pan

The material removal rate is the difference between the weights of work piece before and after machining per unit time. The weights are measured using the weighting machine which is shown in Figure 3.The Inconel-601 is selected for the dissertation work by considering its characteristics and wide applications stated in 1.3. By keeping in mind the limitations and suggestions by respected guide and examination panel the following dimensions of work piece is selected.

Length = 100mm, Breadth = 30mm and Thickness = 2.1mm

For carrying out experimentation on Inconel-601 by using WEDM process, the zinc coated brass hard EDM wire of 200 µm diameter is used.

IV. DESIGN OF EXPERIMENTS (DOE) BY USING TAGUCHI METHOD

Taguchi method is used for experimentation of WEDM process on Inconel-601 to find the best possible combination of input variables to make the WEDM process "robust". The experiments are planned and designed as per Taguchi method by using Minitab software. Taguchi method provides increase in quality of process and reduces the variations in results. For my dissertation experiments, Taguchi method is used to obtain the design of experiments. By using Taguchi method, Total number of experiment $=\text{Level}^{\text{Factors}}$. Taguchi's DoE is a statistical approach to determine the minimum number of experiments required to be performed in order to get near optimum output parametric values. In this case it suggests performance of two different sets of experiments. These sets of experiments are in array. The input variables and levels for input variables for dissertation experiments is stated in Table 1.

Table-1: Input variables and levels.

Parameters ↓	Level no 1	Level no 2	Level no 3
Voltage (Volts)	150	175	200
Pulse on time (μsec)	60	80	100
Parameter ↓	Level no 1	Level no 2	
Capacitance (pF)	1000	10000	

Orthogonal array is the minimum number of experiments to be performed. As per the input variables and their levels, the L_{18} orthogonal array is suggested by the Minitab software by using Taguchi method.

V. EXPERIMENTS AS PER DOE AND EXPERIMENTAL RESULTS

The experiments were performed as per L_{18} array. The results of these experiments is stated in Table 2.

Table-2: Experimental results

Experiment No.	Capacitance (pF)	Voltage (V)	Pulse On Time (μsec)	MRR (mm^3/min)	Surface Roughness Ra (μm)
1.	1000	150	60	0.00647	0.20
2.	1000	150	80	0.00198	1.15
3.	1000	150	100	0.00281	1.30
4.	1000	175	60	0.00292	1.72
5.	1000	175	80	0.01027	1.92
6.	1000	175	100	0.00308	2.10
7.	1000	200	60	0.00770	2.53
8.	1000	200	80	0.01027	2.92
9.	1000	200	100	0.01049	2.90
10.	10000	150	60	0.01722	3.05
11.	10000	150	80	0.01819	3.31
12.	10000	150	100	0.01335	3.53
13.	10000	175	60	0.01849	3.75
14.	10000	175	80	0.01644	3.81
15.	10000	175	100	0.02055	3.91
16.	10000	200	60	0.02849	3.35
17.	10000	200	80	0.03288	3.86
18.	10000	200	100	0.03380	3.92

VI. ANALYSIS OF RESULTS BY USING ANALYSIS OF VARIANCE (ANOVA)

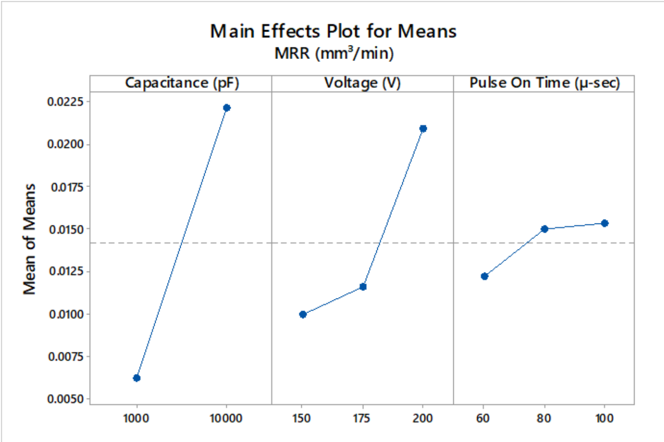
Taguchi method uses statistical analysis to confirm the best level of input variables. This allows us to study particular process and analyse effect of process parameters on responses with minimum amount of experimentation, which results is reduced time and resources. The signal to noise ratio is calculated to check the quality characteristics for output variables. Signal refers to the desired value while noise refers to the factors that cause deviation in the process. Thus, higher the S/N ratio value, better the results for that input variable. As per the quality of output variables required, the quality loss function is categorized as follows.

1. Smaller the better
2. Larger the better
3. Nominal the best

The fitness of the model to the obtained results is given by R-sqvalue. Greater R-sq indicates that the obtained data fits at higher rate to the model.

1. Experimental result analysis for MRR (mm^3/min)

For MRR larger the better signal to noise ratio is selected. The graphs are plotted by using mean of means of all result values (Y axis) V/S input capacitance, voltage and pulse on time.



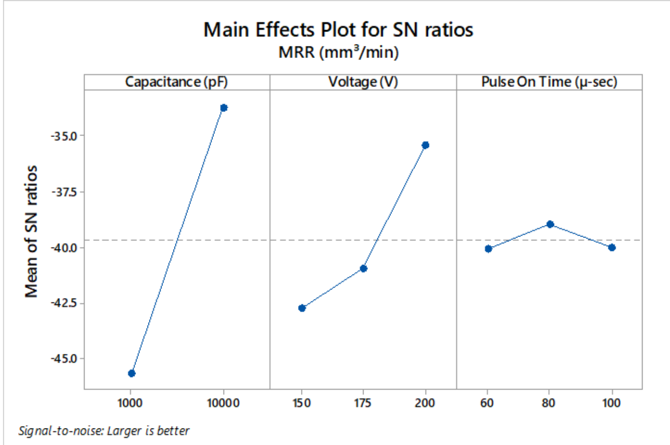


Fig-4: Main effects plot of means for MRRFig-5:Main effects plot of S/N ratio for MRR

Table-3: ANOVA results for MRR

	P value	F value	% Contribution
Capacitance (pF)	0.000	33.22	56.86
Voltage (V)	0.015	6.09	20.85
Pulse On Time (µsec)	0.613	0.51	1.74

R-sq = 76.46%

2. Experimental result analysis for average Surface roughness (SR) (µm)

For Surface roughness, smaller the better signal to noise ratio is selected.

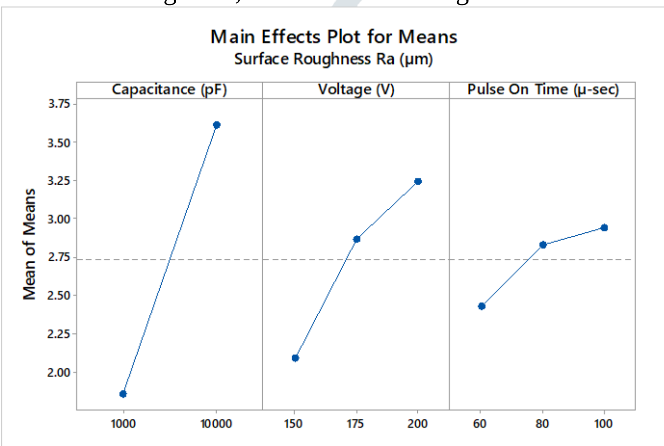


Fig-6. Main effects plot of means for SR

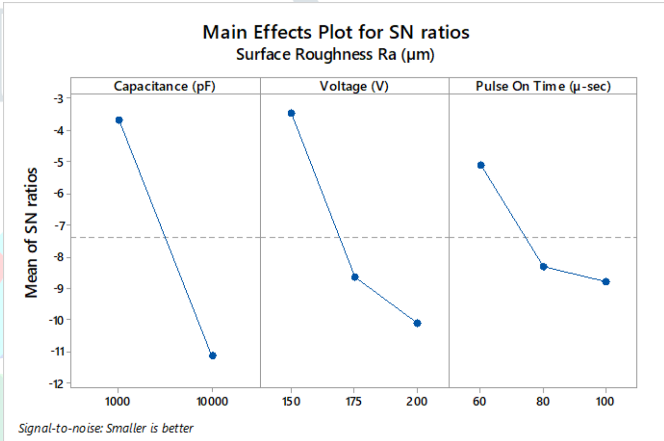


Fig-7. Main effects plot of S/N ratio for SR

Table-4: ANOVA results for average surface roughness

	P value	F value	% Contribution
Capacitance (pF)	0.000	80.21	66.02
Voltage (V)	0.001	12.15	19.99
Pulse On Time (µsec)	0.124	2.50	4.11

R-sq = 90.12%

VII. CONCLUSIONS

1. For MRR as well as Surface roughness, Capacitance is found to be most influencing parameter.
2. Increase in capacitance, voltage and PoT increases MRR as well as SR.
3. The optimum set of input variables for MRR are Capacitance = 10000 pF, Voltage = 200 V, PoT = 100 µ-sec.
4. The optimum set of input variables for SR are Capacitance = 1000 pF, Voltage = 150 V, PoT = 60 µ-sec.
5. The better S/N ratio for MRR was observed at Capacitance = 10000 pF, Voltage = 200 V, PoT = 80 µ-sec.
6. The better S/N ratio was observed at Capacitance = 1000 pF, Voltage = 150 V, PoT = 60 µ-sec.

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