Optimization of Machining Parameters in Machining Inconel 600 by Wire Electric Discharge Machining

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Abstract **— The purpose of this study is to optimize the machining parameters and hence to analyze the characteristics of surface integrity with machining parameters. The specimen material used for this study is Inconel 600. The machining parameters considered for this study are Pulse ON Time, Pulse OFF Time, Peak Current and Bed speed. The Surface characteristics considered for this study are Surface roughness and Recast layer thickness. The experiments are carried out by using Taguchi's L_9 orthogonal array. The effect of each machining parameter on the surface integrity is quantified. Based on the effect, optimum machining parameters are identified. A verification experiment is conducted using optimum machining parameters, to show the reduction in surface roughness and reduction in recast layer thickness.**

Keywords— WEDM, Inconel 600, Recast layer, Design of experiments, Surface characteristic.

I. INTRODUCTION

Electric discharge machining (EDM) is a thermal material removal process in which the work piece material is removed by local melting or vaporizing small areas at the surface of work piece. The EDM process removes material by controlled erosion of the material by repetitive electric sparks between the work and tool submerged in a dielectric medium. Wire electric discharge machining (WEDM) is a type of EDM process. In WEDM process the tool is a wire that travels through the work piece to cut it.
Inconel 600 is chosen as work piece material. It is a nickel alloy which is difficult to machine using conventional machining process.

II. LITERATURE REVIEW

Che-Chung Wang et al [1], explored the feasibility of removing recast layer using etching and mechanical grinding for nickel alloy materials. After experimental machining, SEM was used to measure the recast layer thickness. It was concluded that positive polarity created thicker recast layer then negative polarity and chemical erosion with optimum conditions removed recast layer effectively. It was concluded that EPMA analysis and micro hardness were yielded better results to prove that the recast layer was removed.

Hsien-Ching Chen et al [2], analyzed the effect of WEDM machining parameters on cutting velocity and surface finish of the work piece. Back propagation neural network (BPNN) and simulated annealing algorithm (SAA) was integrated to determine the optimum combination. It was concluded that BPNN was successful in prediction of cutting velocity and roughness. The Pulse ON time was the most influencing factor against cutting velocity and surface finish.

Zhaoqi Zeng et al [3], experimented combined milling of micro-EDM and micro-ECM. The rough machining was carried out by micro-EDM and the finishing was carried out by micro-ECM. The machining voltage, tool feed rate and machining gap were the machining parameters considered. By micro-ECM finishing the recast layer, micro pores and craters were removed completely. The feed rate had the major effect on surface finish.

T. Tamura et al [4], analyzed the development of surface modification technology in EDM. The surface defects were eliminated using the sinking electric discharge machine. The machined surface was observed by scanning electron microscope to analyze the recast layer. It was concluded that the recast layer was selectively removed by the dissolution of cobalt as a result of electrolytic action.

J.W. Murray et al [5], studied the characterization of microstructural changes, presence of any contaminants and defects at the nano level with the help of transmission electron microscope and laser Raman spectroscopy. It was observed that, during re-solidification of the molten surface, there were some microstructural changes present. The deposition of tool material was detected in the recast layer.

Farnaz Nourbakhsh et al [6], investigated the effect of machining parameters on process parameters in WEDM. It was concluded that, cutting speed increase with Peak current and pulse interval. Surface roughness increased with increase in Pulse width and decreased with increase in Pulse interval. SEM examination proved that, Zinc coated wire resulted in higher cutting speed and smoother surface finish.
Based on the Literature survey the main objective of this work is taken as optimization of machining parameters to get smoother surface roughness.

III. EXPERIMENT

The WEDM process has many machining parameters. Based on the literature survey and the experience of the machine operator it is found that, Pulse ON time, Pulse OFF time, Peak current and Bed speed have the major effect on surface roughness and hence those parameters are focused for the investigation.

The machining experiments are planned scientifically based on the concept of Design of Experiments (DOE). The type of DOE chosen for this work is Taguchi's orthogonal array.

Number of levels of the orthogonal array is chosen based on the machine capability.

TABLE 1. INPUT MACHINING PARAMETER VALUES ASSIGNED

Control Factors	Level 1	Level 2	Level 3
Pulse ON Time (µs)	3	5	7
Pulse OFF Time (µs)	22	26	30
Peak Current (ampere)	1	2	3
Bed speed (µ/s)	55	70	85

TABLE 2. L_9 ORTHOGONAL ARRAY WITH ASSIGNED VALUES

Experiment No.	Pulse ON Time (µs)	Pulse OFF Time (µs)	Peak Current (ampere)	Bed speed (µ/s)
1	3	22	1	55
2	3	26	2	70
3	3	30	3	85
4	5	22	2	85
5	5	26	3	55
6	5	30	1	70
7	7	22	3	70
8	7	26	1	85
9	7	30	2	55

The machining is carried out on Sodic Machine.
Molybdenum wire of 0.18mm diameter is used as the tool electrode and De-ionized water is used as the dielectric liquid.
Inconel 600 is chosen as the work piece material. The work piece dimensions are 10mm x 10mm x 15mm.
After machining, surface roughness is measured using SURFTEST SJ-210 surface roughness tester. Using Scanning Electron Microscope, images of the machined surface are captured and thickness of the recast layer on each work piece is measured.

IV. RESULTS AND DISCUSSION

TABLE 3. SURFACE ROUGHNESS

Experiment No.	Roughness, R_a (µ)
1	1.699
2	1.452
3	1.745
4	1.617
5	1.773
6	1.885
7	1.921
8	1.538
9	1.895

TABLE 4. RESPONSE TABLE FOR S/N RATIO OF SURFACE ROUGHNESS

Level	Pulse ON Time (µs) (A)	Pulse OFF Time (µs) (B)	Peak current (ampere) (C)	Bed speed (µ/sec) (D)
1	-4.226	-4.816	-5.312	-5.043
2	-4.885	-4.500	-4.332	-4.805
3	-5.503	-5.298	-5.160	-4.766
Delta	1.277	0.798	0.838	0.278
Rank	1	3	2	4

Based on the experiments, the optimum set of parameters is A3 B3 C1 D1 to get smoother roughness.

Level 3 of A, Level 3 of B, Level 1 of C and Level 1 of D are having the smaller signal to noise ratio.

Thus A3 B3 C1 D1 is the best combination i.e. Pulse-ON Time (7µs), Pulse-OFF Time (30 µs), Peak current (1 ampere) and Bed speed (55 µ/s).

TABLE 5. RECAST LAYER THICKNESS

Experiment No.	Recast layer thickness (µ)
1	2.5
2	2.4
3	2.9
4	3.9
5	7.0
6	7.3
7	9.0
8	4.6
9	10.5

TABLE 6. RESPONSE TABLE FOR S/N RATIO OF RECAST LAYER THICKNESS

Level	Pulse ON Time (µs) (A)	Pulse OFF Time (µs) (B)	Peak current (ampere) (C)	Bed speed (µ/s) (D)
1	-8.270	-12.955	-14.164	-15.095
2	-15.330	-13.924	-13.283	-14.652
3	-18.925	-15.646	-15.078	-12.779
Delta	10.665	2.691	1.795	2.316
Rank	1	2	4	3

Based on the experiments, the optimum set of parameters is A3 B3 C3 D1 to get minimum Recast layer thickness.

Level 3 of A, Level 3 of B, Level 3 of C and Level 1 of D are having the smaller signal to noise ratio.

Thus A3 B3 C3 D1 is the best combination i.e. Pulse-ON Time (7µs), Pulse-OFF Time (30 µs), Peak current (3 ampere) and Bed speed (55 µ/s) .

TABLE 7. OPTIMIZED PARAMETERS TO OBTAIN SMOOTHER SURFACE ROUGHNESS

Pulse ON Time (µs)	Pulse OFF Time (µs)	Peak current (ampere)	Bed speed (µ/s)	Surface roughness (µ)
7	30	1	55	0.812

TABLE 8. OPTIMIZED PARAMETERS TO OBTAIN MINIMUM RECAST LAYER THICKNESS

Pulse ON Time (µs)	Pulse OFF Time (µs)	Peak current (ampere)	Bed speed (µ/s)	Recast layer thickness (µ)
7	30	3	55	2.35

The optimum machining parameters obtained from the analysis are verified by conducting verification experiment. The optimum machining parameters results are better than the results obtained from the experimental machining parameters.

V. CONCLUSION

It is concluded that the Pulse ON time has more effect, Peak Current and Pulse-OFF time have lesser effect and Bed speed has least effect on the surface roughness and recast layer thickness. More number of experiments can be performed to analyze the trend of effect of input parameters on the output parameters of the machining process. More number of output parameters can be considered for further analysis.

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