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Effect of Work-piece Thickness on the Responses Surface Roughness and MRR in Wire-EDM of AL6063-T6 Alloy

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Abstract:- Now a days *high value-added* to manufacturing section is essential under the situations of the high precision requirements of industrial products or the high labor cost. Wire-cut EDM is one of the modern cutting technologies is high precision cutting for thickness work-pieces. This method is capable of quickly and easily cutting complex shapes while achieving very high tolerances. The present study is on effect of work-piece thickness on responses w.r.t process parameters. The operation was performed on the aluminum alloy AL6063-T6 using L8-Orthogonal array of Taguchi method. The measuring responses are surface roughness (Ra) and Material Removal Rate (MRR) with input parameters as work-piece thickness (w/p-t), pulse on time (Ton), pulse off time (Toff), wire tension (WT), wire feed (WF) and dielectric flushing pressure (WP). Result data was analyzed using Minitab software with the help of ANOVA, contour plots, surface plots and multi response optimization. Ra is decreasing with increasing of work-piece thickness and Ra is increasing with decreasing of work-piece thickness w.r.t process parameters. MRR is increasing with increasing of work-piece thickness and MRR is decreasing with decreasing of work-piece thickness w.r.t process parameters.

Keywords:- *Wire-cut EDM, AL6063-T6, Taguchi, ANOVA, Ra, MRR, w/p-t, Ton, Toff, WT, WF and WP.*

I. INTRODUCTION

Wire EDM is one of the most efficient and cost-effective ways to machine electrically conductive and hard materials with extreme accuracy. This method is capable of quickly and easily cutting complex shapes while achieving very high tolerances. It is also a no impact cutting method, meaning it can machine fragile, brittle, and hard materials without the risk of distortion.

Wire EDM uses a thin wire composed of copper or brass to conduct electrical current between an electrical source and an electrically conductive base material. The current creates sparks capable of cutting the substrate into pre-programmed designs. The material is submerged in de-ionized water to prevent overheating or warping, facilitating smooth and precise cuts. Wire EDM is especially valuable for the creation of extremely intricate shapes, complex designs, and geometric angles that are difficult or impossible to create using other manufacturing techniques. The accuracy of the wire EDM process is heavily dependent on cutting parameters and speed. At higher speeds, the wire can slightly move or bend, affecting overall accuracy. To ensure the highest possible accuracy, it is best to maintain lower power and speed. With higher speeds, tolerances of +/- 0.001’’ are achievable, while tolerances of up to +/- 0.0002’’ are achievable with lower power and speed. The major parameters are;

1)Pulse on Time - It is the duration of time for which the current is allowed to flow in each cycle and is expressed in micro seconds (µs).
2) Pulse off Time – It is the duration of time between two simultaneous sparks and is expressed in micro seconds (µs).
3) Spark Gap - It is the distance between the electrode and the work-piece during the EDM process.
4)Peak Current - It is the maximum value of the current passing through the electrodes for the given pulse and is expressed in amperes (A).
5) Spark Gap Voltage - It gives the specific voltage for the actual gap between the work piece material and the wire and is expressed in volts (V).
6) Wire Feed - The rate at which the wire travels along the wire guide path and is fed for generating the sparks is called wire feed rate.
7) Wire Tension - How much the wire is to be stretched between upper and lower wire guides is determined by the wire tension.
8) Pulse Peak Voltage - Pulse peak voltage setting is for selection of open gap voltage. ***9) Dielectric Pressure -*** Dielectric Pressure is the pressure of the dielectric fluid which surrounds the work piece and the wire. It is the rate at which this fluid is circulated in the tank.

II. LITERATURE REVIEW

Past researchers have used various methods and techniques to optimize the machining parameters during wire EDM of different materials. Nilesh T. Mohite et.al. used Taguchi method for designing the experiments. Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method is used to get optimum parametric combination. [1]. Jaskarn Singh et.al. reviews the effect of WEDM process parameters such as pulse on time, pulse off time, servo voltage, peak current, dielectric flow rate, wire speed, wire tension on different process response parameters such as material removal rate, surface roughness and wire wear ratio. [2]. S. V.

S. S. Sriniavasa Raju et.al. used statistical tool ANOVA and L9 Orthogonal Array to optimize the machining parameters like surface roughness and material removal rate. [3]. M. Durairaj et.al. used Taguchi L16 Orthogonal Array for experiment design and Taguchi optimization technique and ANOVA for optimization of surface roughness and kerf width. [4]. Pujari Srinivasa Rao et.al. studied on parametric analysis of wire EDM parameters was performed by Taguchi method on surface roughness, and material removal rate. [5]. A. Muniappan et.al. Taguchi experimental design strategy is used in the experimentation. Six process parameters, namely pulse on time, pulse off time, peak current, gap set voltage, wire feed and wire tension have been considered. Cutting speed, kerf width and surface roughness is calculated for each experiment. He stated diffused coated wire electrode's performance is better than the other wire electrodes. [6]. Magesh. M et.al. experiments were planned on ss410 material as per Taguchi's Orthogonal array and Minitab software was applied to predict responses surface roughness and material removal rate. [7]. Shivkant Tilekar et.al. effect of process parameter on surface roughness and kerf width of aluminum and mild steel are investigated and single objective Taguchi method is used for process parameter optimization. [8]. Nishant Saxena et.al. an optimization of wire EDM is performed using Taguchi optimization method. The parameters involved are pulse-on time, pulse-off time, peak current and servo voltage. Cutting rate, Surface Roughness, Dimensional Deviation and Wire Wear Ratio are taken as the responses. [9]. Abhishek Ruhela et.al. the effects of wire cut Electrical Discharge Machining process parameters on quality characteristics viz. cutting rate, surface roughness, gap current and dimensional deviation while machining Aluminium work material, Copper work material Brass work material work material is carried out on of multi objective optimization. [10]. Ankit Umare et.al. This paper reviews the effects of various WEDM process parameters such as pulse on time, pulse off time, servo voltage, peak current, dielectric flow rate, wire speed, wire tension on different process response parameters such as material removal rate (MRR), surface roughness (Ra), Kerf (width of Cut), wire wear ratio (WWR) and surface integrity factors. [11]. Pratik A et.al. The experiments were designed based on response surface design method; the effect of the parameters on MRR was determined by analysis of variance (ANOVA) and Regression analysis was done and a second order mathematical model was fitted for MRR. [12].

III. EXPERIMENTAL METHODOLOGY

Experiments were planned as per Taguchi's orthogonal arrays (OA) are a special set of Latin squares to lay out the product design experiments. The results obtained from the orthogonal array are then analyzed to achieve the following objectives

- To estimate the contribution of influencing factors on Ra and MRR
- To study the effect of work-piece thickness on Ra and MRR w.r.t process parameters.
- To gain the best, or optimum conditions for the process.

➢ *Experiments Design*

Using L8 orthogonal array with 6 factors and two levels and the factors are listed below

S.no.	Independent Variables	Notation	Units	Levels	
				1	**2**
1	w/p thickness	w/p-t	mm	5	10
2	Pulse on-time	T_{on}	µs	5	10
3	Pulse off-time	T_{off}	µs	8	16
4	Wire tension	WT	N	8	12
5	Wire feed	WF	mm/min	4	6
6	Flushing pressure	WP	Kg/cm^2	2	4

Table 3.1: Selection of Independent variables and their levels

Factors assigned to Orthogonal Array shown in table below

S. no	A	B	C	D	E	F	w/ p-t	T on	To ff	W T	W F	W P
1	1	1	1	1	1	1	10	5	8	8	4	2
2	1	1	1	2	2	2	10	5	8	12	6	4
3	1	2	2	1	1	2	10	10	16	8	4	4
4	1	2	2	2	2	1	10	10	16	12	6	2
5	2	1	2	1	2	2	5	5	16	8	6	4
6	2	1	2	2	1	2	5	5	16	12	4	4
7	2	2	1	1	2	2	5	10	8	8	6	4
8	2	2	1	2	1	1	5	10	8	12	4	2

Table 3.2: Assigning Independent variables to Orthogonal Array

➢ *Machine setup*

Experiments are conducted on Excetek EX400 EX Series Submerged Type CNC wire-cut EDM Machine. This machine was suitable to high production unit for maximum output. The machine was with 400x300mm X/Y travel, Z travel up to 220mm, 80x80mm U&V axis travel, taper angle up to +/-22 deg./80mm, wire diameter 0.15 to 0.3mm.

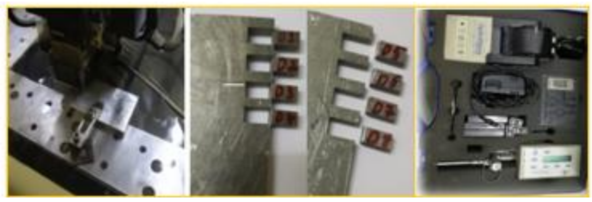

Fig 3.1 WEDM process and work-piece

➢ *Wire Electrode*

A 0.25mm diameter milscut brass wire from MANAN Associates was used as electrode with tensile strength of $900N/mm^2$.

➢ *Work-piece*

Aluminium alloy AL6063-T6 of 5mm and 10mm thick plates of 130x80mm is used as work-piece material for cutting.

➢ *Surface Roughness Measurement*

Ra (surface roughness) was measured by using Taylor Hobson Surface Profilometer.

IV. DATA ANALYSIS

Result data for surface roughness and material removal data shown in table below.

S.no	w/p-t	Ton	Toff	WT	WF	WP	Ra	MRR
	mm	µs	µs	N	mm/min	Kg/cm^2	µm	mm^3/min
1	10	5	8	8	4	2	2.8	12.50
2	10	5	8	12	6	4	2.6	12.50
3	10	10	16	8	4	4	3.0	23.62
4	10	10	16	12	6	2	2.8	24.12
5	5	5	16	8	6	4	2.4	10.56
6	5	5	16	12	4	4	2.6	10.43
7	5	10	8	8	6	4	3.6	12.50
8	5	10	8	12	4	2	3.6	12.50

Table 4.1: Result data of experiment for Ra and MRR

- *ANOVA (Analysis of Variance)*

Analysis of variance for the responses surface roughness (Ra) and material removal rate (MRR) is shown in Table 4.2 and 4.3

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% Of C
Model	6	1.030	0.171667	34.33	0.130	99.52
Linear	6	1.030	0.171667	34.33	0.130	
w/p-t (mm)	1	0.045	0.045000	9.00	0.205	4.35
Ton (µs)	1	0.605	0.605000	121.00	0.058	58.45
Toff (µs)	1	0.245	0.245000	49.00	0.090	23.67
WT (N)	1	0.005	0.005000	1.00	0.500	0.49
WF (mm/s)	1	0.125	0.125000	25.00	0.126	12.08
WP (kg/cm^2)	1	0.005	0.005000	1.00	0.500	0.49
Error	1	0.00500	0.005000			
Total	7	1.03500		Model value is – 99.52%		

Table 4.2: ANOVA for Ra vs. Process Parameters

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% Of C
Model	6	222.859	37.1431	2170.52	0.016	99.99
Linear	6	222.859	37.1431	2170.52	0.016	
Thickness (mm)	1	89.445	89.4453	5226.90	0.009	40.13
Ton (µs)	1	89.445	89.4453	5226.90	0.009	40.13
Toff (µs)	1	43.852	43.8516	2562.55	0.013	19.68
WT (N)	1	0.017	0.0171	1.00	0.500	0.007
WF (mm/s)	1	0.050	0.0496	2.90	0.338	0.022
WP (kg/cm3)	1	0.050	0.0496	2.90	0.338	0.022
Error	1	0.017	0.0171			
Total	7	222.876		Model value is - 99.99%		

Table 4.3: ANOVA for MRR vs. Process Parameters

- *Surface Plots*

Surface plot shows a functional relationship between a designated dependent variable (Y), and two independent variables (X and Z). A surface plot is like a wireframe plot, but each face of the wireframe is a filled polygon. This can aid perception of the topology of the surface being visualized.

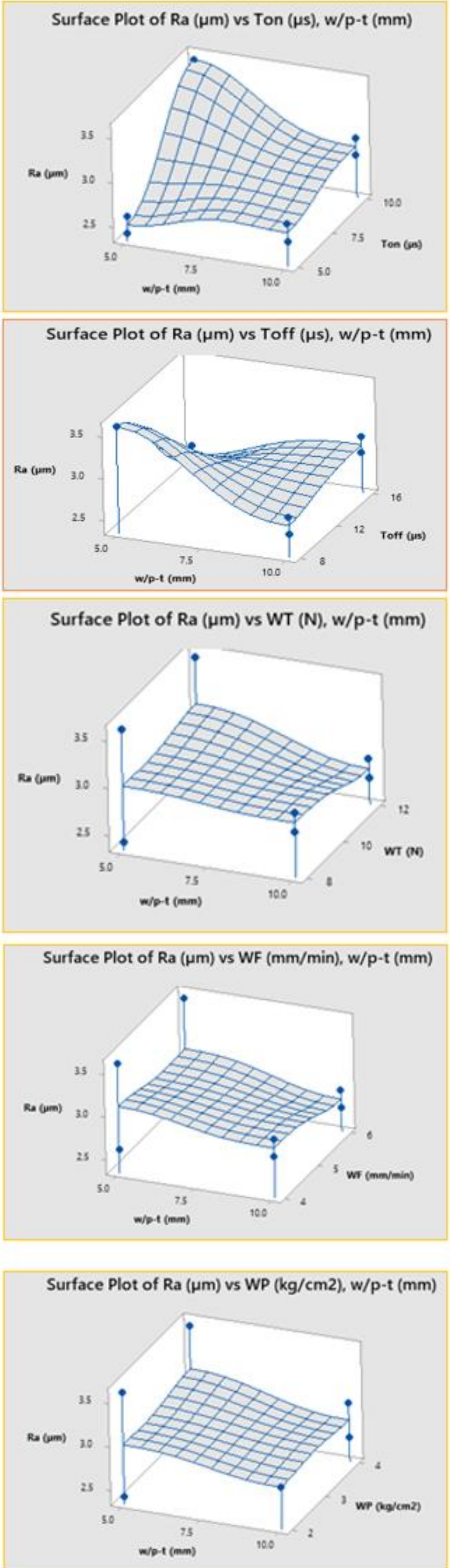

Fig 4.1: Surface Plots of Ra vs. w/p-t w.r.t Process Parameters

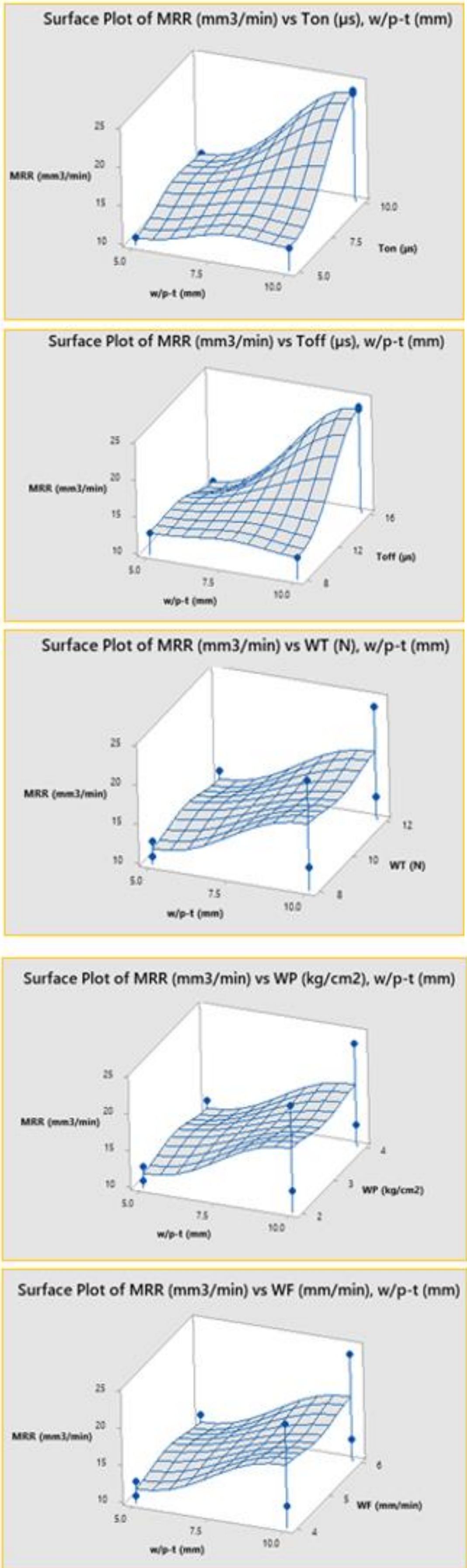

Fig 4.2: Surface Plots of MRR vs. w/p-t w.r.t Process Parameters

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➢ *Response Optimization*

- ***Response:*** Surface Roughness (Ra)

Goal: Minimum and target is 2.4
Solution: w/p-t = 10mm, Ton=5µs, Toff=16µs, WT=8N, WF=6mm/min and WP=4kg/cm^2
Ra = 2.175µm

Composite desirability: 1

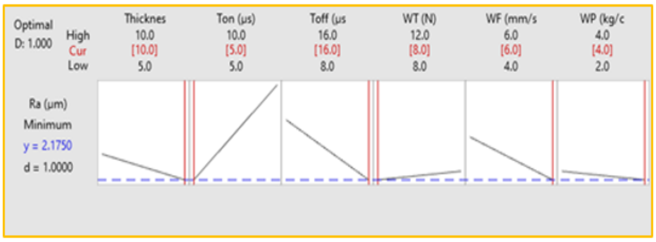

Fig 4.3: Optimization of Ra vs. Process Parameters

- ***Response:*** Material Removal Rate (MRR)

Goal: Maximum and target is 24.12
Solution: w/p-t = 10mm, Ton=10µs, Toff=16µs, WT=12N, WF=6mm/min and WP=2kg/cm^2
Ra = 24.738 mm^3/min
Composite desirability: 0.99

V. CONCLUSIONS

This paper has presented on effect of work-piece thickness on Ra and MRR, finding the percentage of contribution of factors effecting the responses Ra and MRR and setting of predict values to factors at optimum levels of the responses Ra and MRR. The final results are listed below.

➢ The percentage of contribution occupied by the factors as 85.45% by Ton, 23.67% by Toff, 12.08% by wire feed, 4.35% by w/p thickness and 0.49% by wire tension and flushing pressure which effects on the response surface roughness.
➢ The percentage of contribution occupied by the factors as 40.13% by Ton, 40.13 by w/p thickness, 19.68% by Toff, 0.022% by wire feed and flushing pressure and 0.007% by wire tension which effects on the response MRR.
➢ Ra is decreasing with increase of w/p thickness and with increase of pulse on time, pulse off time, wire tension, wire pressure and flushing pressure.
➢ Ra in increasing with decrease of w/p thickness and with increase of pulse on time, pulse off time, wire tension, flushing pressure and with increase/decrease of wire feed.
➢ MRR is increasing with increase of w/p thickness and with increase of pulse on time, pulse off time, wire tension, wire feed and flushing pressure.
➢ MRR in decreasing with decrease of w/p thickness and with increase/decrease of pulse on time, pulse off time, wire tension, wire feed and flushing pressure.
➢ The response surface roughness (Ra) is optimized to minimum with the parametric combination of higher level of w/p thickness, pulse off time, wire feed, flushing pressure and with lower level of pulse on-time and wire tension.
➢ The response MRR is optimized to maximum with the parametric combination of higher level of w/p thickness, pulse on time, pulse off time, wire tension, wire feed and lower level of flushing pressure.

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