Investigation Of WEDM Process Parameter For Surface Roughness And MMR Of AA6063 Aluminium Alloy

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ABSTRACT

As wire cut electro discharge machining is spearheaded as an incredible, productive and exact and complex nontraditional machining strategy, inquire about is required here for effective machining. In this research study, we are applying the pulse on time , pulse off time , wire feed & tension as input parameters whereas surface roughness and material removal rate are considered as output parameters. The design of experiments will be done by applying L9 orthogonal arrays method and experiments will be conducted. The objectives of the project are to maximize the material removal rate and to minimize the surface roughness value (Ra) and this parameters are analyzed for AA6063 material.

Keyword : Wre cut electro discharge machining , pulse on time, surface roughness, L9 orthogonal array.

1. INTRODUCTION

Recent developments in mechanical industry have demand of materials of high toughness, hardness, impact resistance and this materials are difficult to machine by traditional machining process. Also the competitiveness market demands high speed machining with less lead time with greater accuracy. Fulfilling of this requirements are achievable by using nontraditional machining like EDM, LBM, USM. Wire cut electro discharge machining provides very versatile applications in fields like fabrication of stamping and extrusion tools and dies, fixtures and gauges, prototypes, aircraft and medical parts and Grinding wheels form tools, critical machining to small and delicate parts with different profiles.

Zahid A. Khana et al [1] studied the multi response optimization in WEDM using Taguchi (L-16) orthogonal array. They considered three responses namely material removal rate, surface roughness, and wire wear ratio. This paper carried a study on the effect of the WEDM process parameters on the surface roughness average and the kerf width of the stainless steel (SS 304). Nine experimental runs based on an L9 orthogonal array of Taguchi method and grey relational analysis method is applied to evaluate an optimal WEDM parameter setting. Surface roughness and kerf width are considered as output for this study. After study their conclusion is Pulse ON time is found to be the most influential factor for both the surface roughness and the kerf width.

M. Durairaja, D. Sudharsunb [2] investigated the effect of spark cycle on MRR and surface integrity of four types of advance materials. This paper used the Grey relational theory and Taguchi optimization technique, to optimize the cutting parameters in Wire EDM for SS304. In this present study work piece used is stainless steel 304 , brass wire of 0.25mm diameter used as a tool and L16, orthogonal array has been used. The input parameters selected for optimization are gap voltage, wire feed, pulse on time, and pulse off time and output parameters they had taken as kerf width & surface roughness, as a result of their study is Increase in the pulse ON time leads to the increase in both the surface roughness and the kerf width and vice versa and Increase in the pulse current leads to the increase in the surface roughness.

G. Venkateswarlu, P. Devaraj [5] presents the optimization of wire electrical discharge machining (WEDM) process parameters such as pulse on time, pulse off time and wire tension to yield maximum material removal rate and minimum surface roughness of copper by using Taguchi and ANOVA. The results indicate that pulse on time is the most significant factor influencing the MRR and Ra followed by pulse off time and wire tension.

Daneshmand et al. [6] studied Taguchi's method for the design of experiments, L18 orthogonal array and the 'Minitab' software program have been used. The experiments indicate that the parameters of discharge current, voltage, and pulse on time have a direct impact on material removal rate (MRR), and with their increase, MRR increases as well. Tool wear rate (TWR) reduces with the increase of pulse off time and discharge current. The results of analysis obtained for surface roughness indicates that pulse on time and off time have the highest impact on the surface roughness of NiTi alloy.

S.R.Nipanikar [7] studied cutting of D3 Steel material using electro discharge machining (EDM) with a copper electrode by using Taguchi methodology uses input parameters peak current, gap voltage, duty cycle and pulse on time. It is found that these parameters have a significant influence on machining characteristic such as material removal rate (MRR), electrode wear rate (EWR), radial overcut (ROC).

Noor Zaman Khan, Zahid A. Khan [9] studied Surface roughness (Ra) and micro-hardness (µh) are two important output parameters by taking input parameters the pulse on time, pulse off-time, current of the High Strength Low Alloy steel (ASTM A572-grade 50) used multi optimization technique, found that pulse off time is plays important role for surface integrity.

From above literature survey almost no work is carried out on the material aluminum alloy AA6063 having wide applications in building constructions like painted sheet & extrusions, patterned sheet & tread plate. Also, in road transport for road signs plates, castings; in marine industry pipes tubes, architectural fabrication, window and door frames, pipe and tubing, and aluminium furniture are made from this alloy. In this paper Taguchi's DOE approach is used to analyze the effect of WEDM process parameters pulse-on-time, pulse-off-time and wire feed on the material removal rate and surface roughness by using coated wire having zinc coating on the material aluminium alloy AA6063 and optimal setting of these parameters is found that may result in maximizing material removal rate and improvisation of surface roughness.

Table 1: Chemical Composition of Work Material AA6063

Elements	(Si)	(Fe)	(Cu)	(Mn)	(Mg)	(Cr)	(Zn)	(Ti)
Weight Max. %	0.2%	0.35%	0.10%	0.10%	0.45-0.9%	0.10%	0.10%	0.10%

2. METHODOLOGY

Single Response Optimization:

The Taguchi approach is used for evaluating the mean performance characteristics and determination of confidence intervals for the predicted mean has been applied. L9 orthogonal array is used for experimentation setup for four variables as cutting parameter having three levels (shown in Table 2) and two output responses. The Taguchi method is a commonly adopted approach for optimizing design parameters. The method was originally proposed as a means of improving the quality of products through the application of statistical and engineering concepts. ANOM is used to evaluate the optimal levels after experimentation and ANOVA is used to evaluate the contribution of each factor and for F-test. For the analysis of Taguchi Minitab17 software is used.

Taguchi's standard ratios are used to calculate S/N ratio. For minimizing the surface roughness (Ra), which is follows:

Smaller the better:

$$S/N = -10\ \log_{10}\frac{1}{n} \times \sum y2 \qquad (1)$$

Where,

n = no. of total experiments and y = observed surface roughness data

For maximization of material removal rate following equation(2) is used.

Larger is better:

$$S/N = -10\ \log_{10}\frac{1}{n} \times \sum 1/y2 \qquad (2)$$

Where,

n = no. of total experiments and y = observed material removal data

For measurement of surface roughness "SJ210 by Mitutiyo" company made equipment is used which is having cutoff length 5mm. For the material removal rate calculation following equation(3) is used, which has been used by Surinder Kumar et al.[12]

$$MRR = F \times Dw \times H \tag{3}$$

Where, F is machine feed rate in mm/min; Dw is wire diameter used as electrode; H is thickness of work piece.

Figure 1: Experimental setup of Wire cut electro-discharge machining

Figure 2: Work piece before machining and Coated wire used for cutting

Figure 3: Work piece after machining and cut profiles

3. EXPERIMENTATION:

Experiments are performed on Electronica CNC wire electro–discharge machine which is manufactured by ELECTADURACUT, as shown in fig. 1. Work piece plate material is AA6063 having specimen size is 19mm thickness, width of 50mm and length is 200mm. Nine experiments are carried out with different settings of parameter given by orthogonal array. Geometry of cut is decided inclined 20˚ to vertical which is almost maximum inclination of wire while cutting. A coated wire of core brass having zinc coating having diameter 0.25mm is used to erode work piece and electrolytic water was used as the dielectric fluid. Work piece before machining with wire and after machining with the cut profiles is shown in fig. 2 and fig. 3 respectively. By referring the experimental set-up given by orthogonal array; experiments are carried out after which recorded and calculated results of output parameters with input parameters settings shown in Table 2.

Process Parameters:

- Pulse On time:

In pulse on time, discharge spark is on and during this voltage applied in the spark gap between work piece and wire which produce spark. Pulse on time as increases, spark energy increases there by generating more amount of heat energy for spark. It is measured in micro seconds.

- Pulse off time:

Pulse interval, also called as Pulse off time, is also expressed in micro seconds. It's the time between discharges. Off Time has no effect on discharge energy. Off Time is the pause between discharges that allows the debris to solidify and be flushed away by the dielectric prior to the next discharge. If using very low values of T off, may result wire breakage which in turn reduces the cutting efficiency.

- Wire Feed:

Wire feed measured in m/min. As it increases, cutting speed increase and consumption of wire also increases; whether as low feed rate of wire brakes down at high speeds. It should ne optimum to achieve high cutting speeds with no breakage of wire.

- Wire tension:

Wire tension should be enough as it affect surface finish and accuracy of cut. At low tension, may lead to lower cutting speed but to increase surface finish, hence it should be maintain at optimal level to achieve high cutting speed and good surface finish.

Table 2 : Levels of Cutting Parameters

Cutting Parameters	**T ON**	**T OFF**	**Wire Feed**	**Wire Tension**
Level 1	106	54	2	6
Level 2	108	56	3	7
Level 3	110	58	4	8

Table 3: Test data summary for Ra & MRR

Experiment no.	T ON μ_s	T OFF μ_s	Wire Feed m/min	Wire Tension units	S.R.(Ra) μ_m	MRR mm^3/min
1	106	54	2	6	4.058667	6.496
2	106	56	3	7	3.743	7.538

3	106	58	4	8	3.511667	6.3745
4	108	54	3	8	3.51	7.885
5	108	56	4	6	2.396333	7.566471
6	108	58	2	7	3.232667	6.964688
7	110	54	4	7	2.914667	9.2625
8	110	56	2	8	3.37	8.870625
9	110	58	3	6	3.555667	8.745938

4. RESULT AND DISCUSSION:

Analysis of result is carried out by using S/N ratio, response table, response graphs by using the Minitab-17 software. From Table 3; it has been observed that maximum MRR of 9.26mm3/min which is achieved in trail no. 7 having T on 110 µs, T off 54 µs, Wire feed 4m/min and Wire tension is 7. This seems highest MRR achieved at highest pulse on time, lower pulse off time and highest wire feed and moderate wire tension. For Surface roughness it is observed that less Ra is found out at trail no.5 having T on 108µs, T off 56 $\mu_{s,}$ Wire feed 4m/min and wire tension is 6; which resulted least surface roughness 2.396$\mu_{s.}$

Response Table for surface roughness is shown in Table 4 and ANOVA calculation for contribution shown in Table5. From responses table, we found the optimal level combination for the four input parameters for minimum surface roughness value is A_2 B_2 C_3 D_1. Wire Feed contributed more for the surface roughness also pulse on time having 40% contribution in surface roughness whether wire tension having negligible effect on Ra from ANOVA result in Table 5. Figure 4 shows main effect plot for the S/N ratio for surface roughness for smaller is better.

Response Table for the material removal rate and ANOVA calculation is shown in Table 6 & 7 respectively. For maximization of MRR, response table gave optimal level of for parameters that is A_3 B_2 C_2 D_2. In table 7 of ANOVA result, it is concluded that pulse on time having highest contribution (81.79%) and other parameters are having very less effect on increase in MRR. Figure 5 shows main effect plot of S/N ratio for material removal rate.

Table 4: Response Table & ANOM for Surface roughness

Symbol	Cutting Parameter	Mean S/N Ratio			Max - Min(Delta)	Optimal level	Optimized Level of Parameters
		Level 1	Level 2	Level 3			
A	T ON	-11.514	-9.563	-10.288	1.951	-9.563	2,A_2
B	TOFF	-10.789	-9.869	-10.707	0.92	-9.869	2,B_2
C	WF	-10.97	-11.13	-9.264	1.866	-9.264	3,C_3
D	WT	-10.259	-10.316	-10.79	0.531	-10.259	1,D_1

Table 5: Analysis of variance for Surface roughness

Symbol	Cutting parameter	DoF	SS	MS	F	Contribution %
A	T ON	2	5.84	2.92	5.73	40.78
B	T OFF	2	1.55	0.78	1.52	10.85
C	W.F.	2	6.42	3.21	6.30	44.82
D	W.T.	2	0.51	0.25	0.50	3.56

Total		8	14.32			100.00
P. Error		2	0.51	0.25		

Table 6: Response Table & ANOM for material removal rate

Symbol	Cutting Parameter	Mean S/N Ratio			Max - Min(Delta)	Optimal level	Optimized Level of Parameters
		Level 1	Level 2	Level 3			
A	T ON	16.63	17.46	19.04	2.41	19.04	3,A_3
B	TOFF	17.84	18.03	17.26	0.77	18.03	2,B_2
C	WF	17.36	18.11	17.67	0.75	18.11	2,C_2
D	WT	17.56	17.91	17.66	0.35	17.91	2,D_2

Table 7: Analysis of variance for material removal rate

Symbol	Cutting parameter	DoF=no of obs. in group-1	SS	MS	F	Contribution %
A	T ON	2	9.03	4.52	22.39	81.79
B	T OFF	2	0.96	0.48	2.38	8.68
C	W.F.	2	0.85	0.42	2.11	7.70
D	W.T.	2	0.20	0.10	0.50	1.83
Total		8	11.04			100.00
P. Error		2	0.20	0.10085		

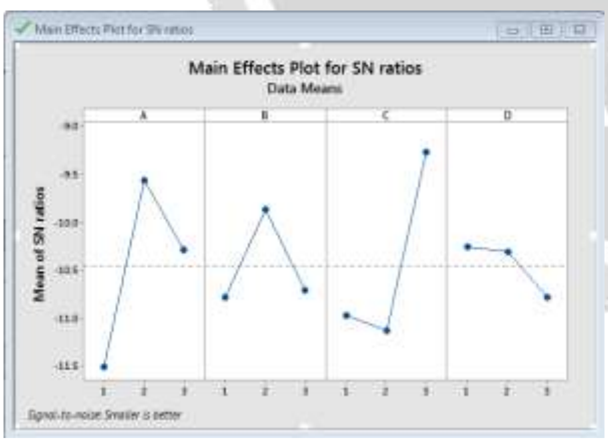

Figure 4: Main effect plot for S/N ratio for surface roughness

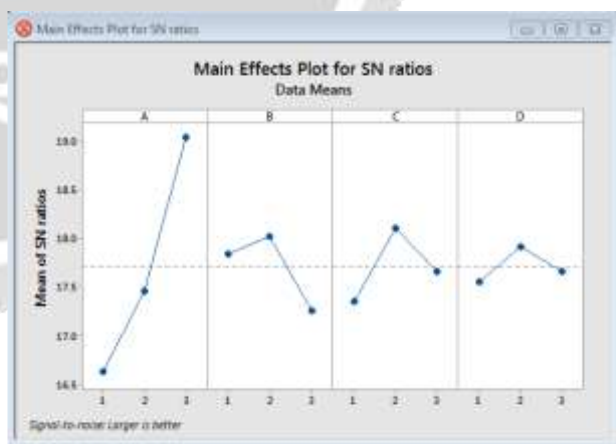

Figure 5: Main effect plot for S/N ratio for material removal rate

Table 8: Single Response Optimization Results

Method	Characteristics	Optimal condition	Optimal Predicted Value
Single Response Optimization	Surface roughness	A_2 B_2 C_3 D_1	2.3961µm
	Material Removal rate	A_3 B_2 C_2 D_2	9.9512 mm^3/min

Table 9: Confirmatory Experimental Result

Response	Predicted value	Optimal Experimental Value
Surface roughness	2.3961µm	2.3963 µm
MRR (mm^3/min)	9.9512 mm^3/min	16.23 mm^3/min

5. CONCLUSION

In this research, the effect of machining parameters on the machining outputs of AA6063 aluminium alloy was investigated experimentally in wire cut electric discharge machining. The optimal surface roughness and material removal rate is predicted at the selected optimal setting of process parameters. The parameters and their selected levels are shown in Table 8. The confirmation experiment done at the optimal settings of the WEDM process parameters recommended by the investigation. Therefore, the optimum surface finish Ra=2.3963 µm & material removal rate is MRR= 16.23mm^3/min was obtained under the earlier-mentioned cutting condition on the WEDM machine.

For maximization of MRR, the highest level of Pulse on time, middle level Pulse off time, moderate level Wire feed and wire tension; whereas minimization of surface roughness middle level pulse on time and pulse off time with highest wire feed rate and lowest wire tension is required.

ANOVA result, for surface roughness it is found that wire feed is most significant factor and wire tension is less contributing factor. For material removal rate it is found that pulse on time is more significant factor than other parameters, while wire tension is less significant factor.

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