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Optimization of Materiel Removal Rate for AL6063-T6 on WEDM Using Response Surface Methodology

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ABSTRACT: AL6063-T6 are gradually becoming very important materials for their scope of uses in manufacturing industries e.g. aerospace, nuclear, automotive, defense, and automobile industries Wire Electric Discharge Machine (WEDM) seems a good option for machining the complicated shapes on metal matrix composite. this paper, identify the effects of various process parameters of WEDM such as pulse on (Ton), pulse off (Toff), Servo voltage (S_v), and wire feed (W_f) for analysis the material removal rate (MRR) while machining AL6063-T6 . Central Composite Design is used to plan and design of experts. The output response variable being material removal rate will be measured for all the number of experiments conducted. As the lowest value of MRR indicates the poor cutting rate, the optimum parameter level combination would be analyzed which gives desired material removal rate. These optimized values of various parameters would then be used in performing machining operation in order to obtain desirable outputs.

KEYWORDS: Metal Matrix Composite, Wire Edm, Process Parameters, Rsm Technique, Material Removal Rate.

I . INTRODUCTION

The main objective of this paper is to study different parameters likes (Ton, Toff, Sv, W_f) of WEDM operations using response surface methodology, in particular central composite design (CCD), to develop empirical relationships between different process parameters and output responses namely MRR. The mathematical models so developed are analysed and optimised to yield values of process parameters producing optimal values of output responses. In 2003 Tosun N, Cogun C; and Pihtili H [1] investigated the effect of cutting parameters on the size of crater erosion on wire electrode. The level of importance of the machining parameters on the wire crater size was determined by utilizing ANOVA. In 2004 Shajan Kuriakose, and M.S. Shunmugam [2] the Wire EDM process is essentially a thermal process and the nature of surface produced is studied. It is observed that more uniform surface characteristics are obtained with coated wire electrode. Among the parameters such as time between two pulses, pulse duration, injection pressure, wire speed and wire tension that has more influence on the surface characteristics, the time between two pulses is the most sensitive parameter. In 2006 Manna A and Bhattacharya B [3] experimentally investigated machining of Al/SiC-MMC by utilizing CNC-Wire cut EDM. Authors studied the various parameters machining of WEDM during machining and established the optimal combination of WEDM parameters for different performance criteria. It was concluded that low input pressure of dielectric is not sufficient to remove the reinforcement particles during machining. Open gap voltage and pulse on time are the most significant and influencing machining parameters for controlling the material removal rate. In 2007 Mahapatra and Patnaik [4] optimized the wire electrical discharge machining parameters . In 2008 J.A. Sanchez et al [5] presented a new approach to the prediction of angular error in wire-EDM taper-cutting. A systematic analysis of the influence of process parameters on angular error is carried out using Design of Experiments (DOE) techniques. A quadratic equation for the prediction of angular error that takes into account electrical parameters and part geometry is derived. Validation results reveal a dominant influence of the mechanical behavior of the wire, rather than that of EDM regime. Following this assertion an original finite element model (FEM) to describe the mechanical behavior of soft wires, typically used in taper-cutting operations, has been developed taking into account non-linear

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phenomena such as contact mechanics, plastic behavior, stress-stiffening and large displacements. Both the results of DoE techniques and FEM simulation have been validated through experimental tests in industrial conditions. Deviations of accuracy of WEDM tapered parts can be reduced to values below 40 using these models. In 2012 Jangra kamal [6] presented a study on unmachined surface area named as surface projection in the die cutting after rough cut in WEDM. Using scanning electron microscope images, length of unmachined surface projections have been determined. Tungsten carbide was used as a work-piece and brass wire as electrode. In 2013 Sharma et al. [7] optimized the process parameters for the cutting speed and dimensional deviation for high strength low alloy steel (HSLA) on WEDM. Response surface methodology was used for the modeling and multi-response optimization. In 2013 R.Chaudhary et al.[8] EN5 is medium strength mild steel so it is widely used in various machineries parts like shafts, racks, pinions, studs, bolts, nuts, rollers etc. Wire Electric Discharge Machine (WEDM) seems a good option for machining the complicated shapes on medium strength steel. this paper, identify the effects of various process parameters of WEDM such as pulse on (Ton) ,pulse off (Toff), peak current (Ip), servo voltage (Sv) for analysis the material removal rate (MRR) while machining EN5 mild steel material. Central Composite Design is used to plan and design of experts. The output response variable being material removal rate will be measured for all the number of experiments conducted. As the lowest value of MRR indicates the poor cutting rate, the optimum parameter level combination would be analyzed which gives desired material removal rate. These optimized values of various parameters would then be used in performing machining operation in order to obtain desirable outputs.In the present study Al/Al₂O₃/SiC MMC is chosen for parametric investigation and optimization of material removal rate by using response surface methodology and Wedm. The rest of the paper is orgainsed as follows. Proposed experimental methodology is explain in section II.Experimental results are presented in section III .Concluding remarks are given in section IV.

Workpiece: Aluminium 6063-T6 is a medium tensile low harden ability carbon steel generally supplied in the cold drawn or turned and polished, or centre less ground condition, with a typical tensile strength range 500 - 850 Mpa, and Brinell hardness range 150 - 245.characterised by good machinability, reasonable Weldability with medium strength plus good ductility. Aluminium 6063-T6 is perhaps the most widely used because of its Extrudability. A structural member of experimental magnetic levitation is also made of Aluminium 6063-T6 mild steel Europe and Japan. Another application of Aluminium 6063-T6 is in welded. Aluminium 6063-T6 extrusions combined with 1580 tube and 289 casting make up the axle body assembly parts of automobiles. Electrical cable towers are also made of Aluminium 6063-T6 extruded shapes. Aluminium 6063-T6 also provides better mechanical properties and is heat treatable and weldable. These are used in pipe and tubing industries and also used in ship and aerospace industries. Aluminium 6063-T6 are usually 15 to 25% lighter steel alloys. Another application of Aluminium 6063-T6 axles, connecting rods, guide rods, hydraulic shafts, motor shafts, rams, spindles, studs, pressure vessels, pipe lines, bridges and other highway structures, door beams, rails etc.

II. EXPERIMENTAL METHODOLOGY

A. Machine Tool: -

In this research work, MRR is response characteristics. These response characteristics are investigated under the varying conditions of input process parameters, which are Ton, Toff, servo gap voltage (SV), wire feed (W_f). The experiments were performed on Electronica make ELEKTRA Sprintcut 734 CNC Wire cut machine. ELEKTRA Sprintcut 734 provides full freedom to the operator in choosing parameter values with in a wide range. A brass wire of 0.25 mm diameter is used as the tool material. Deionized water is used as the dielectric, which flush away the metal particle from the workpiece.

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Fig : 1 WEDM Setup for experimentation.

B. Examining The Output Response-

The MRR (mm^3/min) is calculated from the cutting speed (directly displayed by the machine tool)*length of work piece removed *breadth of work piece removed. i.e $MRR = \text{cutting speed} * \text{length} * \text{Gap Width}$. Values of the MRR are noted at a distance of 5 mm, 5 mm, and 5 mm from the initiation of cut along a particular axis. This is done to ensure that readings are to be noted only when the cutting process is properly stabilised. The offset of the wire is set at zero.

C. Response surface methodology and design of experiment - RSM is a compilation of mathematical and statistical techniques useful for the modeling and analysis of problems in which output factors are influenced by several input parameters and the main aim is to optimize this output parameters[9].

Table 1: Design of experiment and MRR

Std	Run	A:Ton μs	B:Toff μs	C:IP A	D: SV V
1	1	125	60	180	30
2	14	125	60	50	30
3	18	125	20	180	80
4	4	105	60	50	80
5	5	125	20	50	80
6	15	105	20	180	30
7	6	105	60	180	80
8	7	105	20	50	30
9	11	98	40	115	55
10	12	131	40	115	55
11	13	115	6	115	55
12	10	115	73	115	55

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13	2	115	40	5	55
14	21	115	40	224	55
15	8	115	40	115	12
16	20	115	40	115	97
17	17	115	40	115	55
18	3	115	40	115	55
19	16	115	40	115	55
20	9	115	40	115	55
21	19	115	40	115	55

III. RESULT AND DISCUSSION

There are 21 experiments in total carried out according to the design of experiments. The average values of Mrr (mm³/min) are shown in Table 1. For analysis of data, checking the goodness of fit of model is required. The model adequacy checking includes test for significance of regression model, test for significance on model coefficients, and lack of fit test .For this purpose, ANOVA is performed.

Analysis Of Material Removal Rate-

According to the fit summary obtained from analysis, it is found that quadratic model is statistically significant for MRR. The results of the quadratic model for MRR in the form of ANOVA are presented in Table 2. If the F value is more corresponding, p value must be less corresponding resulting in a more significant corresponding coefficient. Non significant terms are removed by backward elimination for the fitting of MRR in the model. Alpha out value is taken at 0.05 (i.e., 95 % confidence level). When quadratic model with backward elimination is selected, the model is not hierarchical so the Toff (B in coded form) is hierarchically added. A model is said to be hierarchical if the presence of higher-order terms (such as interaction and second-order terms) requires the inclusion of all lower-order terms contained within those of higher order. It is found from Table 2 that F value of the model is 149.3925 and related p value is <0.0001, results of a significant model. The lack of fit is a measure of the failure of the model to represent data in the experimental domain at which points are not included in the regression variations in the model that cannot be accounted for by random error. If there is a significant lack of fit, as indicated by a low probability value, the response predictor is discarded . The lack of fit is non significant and its value is 0.1953. From Table 2 it is found that R² of the model is 0.9955, which is very close to 1. The meaning behind this is that 99.55 % variation can be explained by this model and only .45% of total variation cannot be explained, which is an indication of good accuracy. The predicted R² is in logical concurrence with the adjusted R² of 0.97 Figure (3) shows the normal probability plot of residuals for MRR. Most of the residuals are found around the straight line, which means that errors are normally distributed. Adequate precision compares the significant factors to the non significant factors, i.e., signal to noise ratio. According to the results obtained from the software, ratio greater than 4 is desirable. In this, the adequate precision is 44.37. So the signal to noise ratio is significant. By applying multiple regression analysis on the experimental data, the empirical relation in terms of coded factors is obtained as follows:

$$MRR = -57.08 + 2.7 * Ton - 2.56 * Toff + 14.24 * Ip - 12.47 * Sv - 14.39 * Ton * Toff + 10.15 * Ton * Ip + 5.41 * Ton * Sv + 6.78 * Toff * Sv - 9.66 * Toff^2 - 8.88 * Ip^2 - 0.931 * x * Sv^2$$

From Eq. , it is concluded that the main effects of Ton, Toff, Sv and Wf two-factor interaction between combination of various input parameters which have significant effects on MRR.

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Table 2 : ANOVA for response surface of reduced quadratic model of Material Removal Rate

Pooled ANOVA for Response Surface Reduced Quadratic Model						
Analysis of variance table [Partial sum of squares]						
Source	Sum of Squares	df	Mean Square	F Value	p-value Prob> F	
Model	15925.38	11	1447.762	83.52554	< 0.0001	Significant
A-Ton	4134.223	1	4134.223	238.5152	< 0.0001	
B-Toff	37.18669	1	37.18669	2.145407	0.1770	
C-Ip	2771.018	1	2771.018	159.868	< 0.0001	
D-Sv	879.9852	1	879.9852	50.76887	< 0.0001	
AB	686.5013	1	686.5013	39.60623	0.0001	
AC	823.4088	1	823.4088	47.50482	< 0.0001	
AD	96.94363	1	96.94363	5.592957	0.0423	
BD	152.346	1	152.346	8.78928	0.0158	
B^2	1401.682	1	1401.682	80.86705	< 0.0001	
C^2	1184.699	1	1184.699	68.34867	< 0.0001	
D^2	1300.994	1	1300.994	75.05811	< 0.0001	
Residual	155.9985	9	17.33316			
Lack of Fit	76.85262	5	15.37052	0.77682	0.6136	not significant
Pure Error	79.14584	4	19.78646			
Cor Total	16081.38	20				
Std. Dev.	4.163311		R-Squared		0.990299	
Mean	38.96014		Adj R-Squared		0.978443	
C.V. %	10.68608		Pred R-Squared		0.935107	
PRESS	1043.57		Adeq Precision		32.959	

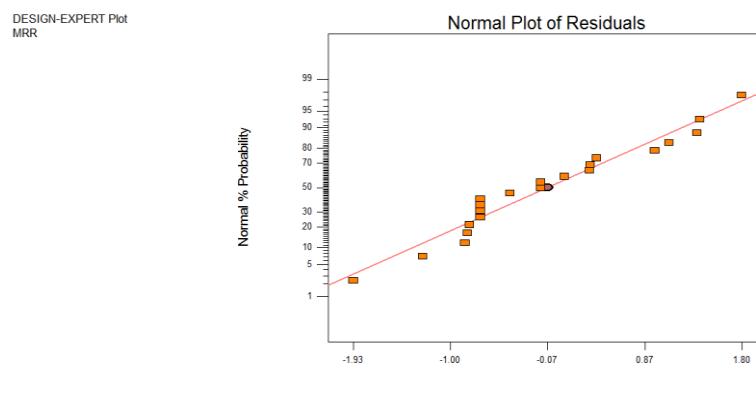


Figure 3 : Normal Probability Plot Of Residuals For MRR

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Effect Of Process Parameter On MRR:

The combined effect of two control factors or process parameters on the response variables is called the interaction effect. For the interaction plot, the two parameters vary keeping other two process parameters at the central value and observe the effect on the response characteristics. This plot is called the three-dimensional surface plot (i.e., 3D surface plot). So the significant interactions are shown in Figs. 3.1(a). The interaction effect (combined effect) of Ton and Toff on MRR (as shown in Figure 3.1 (b) shows that MRR goes to a maximum value 110 mm³/min at a high value of Ton (125) and a low value of Toff (105), while it reaches at a minimum level, where Ton is minimum (105) and Toff is maximum (60). This is due to the fact that higher Ton and lower Toff means that discharge will take place for a long time, long time of discharge means a higher value of discharge energy. A higher value of discharge energy creates violent sparks between the work piece and moving electrode, these sparks causes a faster erosion of material and a faster cutting speed is observed. fig. shows that MRR increases with decrease in the Spark Gap Voltage (SV).The main reason behind this is, higher the Spark Gap Voltage longer the discharge waiting time. To obtain the longer discharge wait time machining speed needs to be slowed down. So lower value of SV favours the productivity.

DESIGN-EXPERT Plot

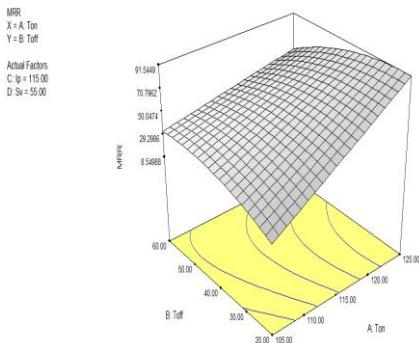


Fig 3.1(a) shows the interaction effect of Ton and Toff on MRR.

DESIGN-EXPERT Plot

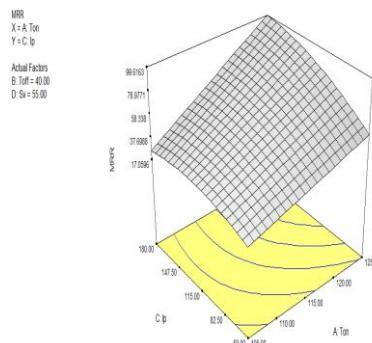


Fig 3.1 (b) shows the 3D interaction plot of Ton and Ip on MRR.

DESIGN-EXPERT Plot

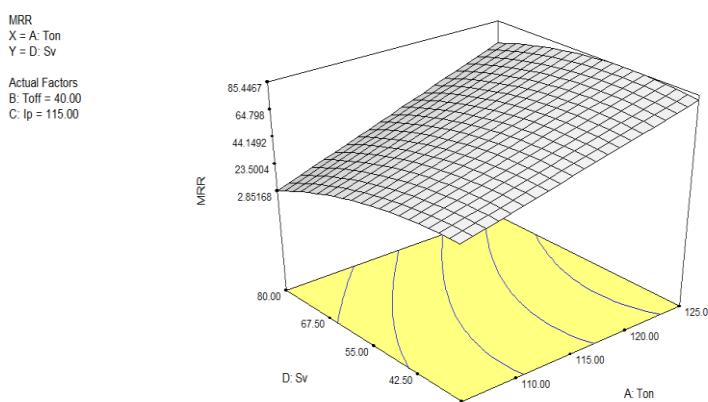


Figure 3.1(c) shows the interaction effect of Ton and Sv on MRR.

IV. CONCLUSION

In this paper, effect of process parameters on MRR is investigated. it is concluded that:

1. For material removal rate Ton, Toff and Sv are the most significant process parameter.
2. For both the response parameters, the predicted values of the responses are in close agreement with experimental results.
3. For material removal rate, the main effects of Ton and Toff are the most significant process parameters. SV, Wf have quadratic function of Toff, two-factor interactions of Ton and Toff, and Ton and Sv play a significant role for response

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variable. Quadratic function of Ton and SV, interaction effects of Toff and SV, and SV and Toff are significant for material removal rate.

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