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Experimental Investigation on Optimization of the Controlling Factors for Machining Al 6061/MoS2 Metal Matrix Composites with Wire EDM

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Abstract

The quality of a Wire EDM surface is strongly influenced by its parameter settings and material to be machined. In the present investigations, the effect of Wire electrical discharge machining (WEDM) parameters such as pulse-on time (T On), pulse-off time (TOff), peak current(Ip) and wire feed (Wf) on material removal rate (MRR) and surface roughness (Ra) in metal matrix composites (MMCs) consisting of Aluminium alloy (Al6061) and MoS2 is discussed. The Al6061 material is reinforced with MoS2 powder of 2 micron particle size with 4% weight ratio. The experiments are carried out based on design of experiments approach using L9 orthogonal array using CNC SPRINTCUT WEDM. The results were analyzed and optimized using analysis of variance and response graphs.

Keywords: Al6061/ MoS2 MMC, ANOVA , Optimization, Response graph , WEDM

INTRODUCTION

The WEDM is the focus of researchers and engineers especially in the field of dies, moulds, precision manufacturing, contour cutting etc. WEDM is a non-traditional process of material removal from electrically conductive materials to produce parts with intricate shape and profiles. The schematic view of WEDM process was shown in fig.1

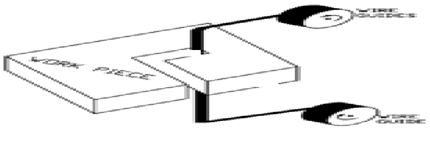

Figure 1: Schematic view of experimental set up

MMCs are materials consisting of two or more constituent parts in which a metal is reinforced with high strength materials such as Sic, MoS2 etc in various proportions. This leads to MMCs with enhanced properties like high strength, high wear resistance etc . However, the reinforcement material in various forms (particulate, whiskers and continuous fibers) makes it difficult to machine using traditional machining methods due to its abrasive nature.

WEDM is considered as one of the most versatile process for machining intricate, complex shapes and difficult to machine materials . A number of research works has been carries out on different materials to study the influence of different process parameters . Al 6061 has the properties of high corrosion resistance, and good machinability. Because of these properties it is commonly used for construction of air craft structures such as wings and fuselages. In the present investigation, Aluminium alloy 6061 was used as the matrix material. Among the various Aluminium alloys, Aluminium alloy 6061 is typically characterized by properties such as fluidity, corrosion resistance, castability and high strength – weight ratio . When Aluminium matrix is reinforced with the hard ceramics particles like SiC, MoS2, Al2O3 and B4C etc its strength increases.

Tirumavalan, k et al [1] optimized the process parameters during machining of AA6061 by Severe Surface Mechanical Treatment (SSMT). By using Taguchi design of experiments the process parameters were optimized. ANOVA is used to analysis of the results. Sankara Narayanan G et al [2] investigated the effect of process parameters on the thickness of the work piece, time and wear and developed mathematical relationships using Artificial Neural Networks. From that they developed Algorithm for the input parameters and the processs parameters by using Wire Cut Electric Discharge Machining.

Ashish Srivastava , Amit Rai Dixit [3] presented an experimental study on composite of Al2024 reinforced with

SiC to investigate the effects of WDEM and Response Surface methodology was applied to optimize the machining parameters for maximize the MRR and Surface finish. Pragya Shandilya and P.K.Jain [4] optimized the process parameters during machining of Al6061/ Sic MMC by WEDM . The input parameters of WEDM namely pulse-on time, pulse- off time, wire feed were chosen as variables. ANOVA results were used to find out the contribution of parameters on MRR and Surface roughness. Sateesh Kumar Reddy and Ramesh S [5] made an attempt to find the optimization of wire electrical discharge machining of Al/SiC MMC. The experiments were carried out to find the best affecting parameters for maximize MRR & Surface Roughness. Taguchi method was used as the Design of Experiment and for the analysis. ANOVA is used for the development of mathematical correlation equation.

Mahapatra and Patnaik [6] made an attempt to determine the important machining parameters for performance measures like material removal rate,surface finish and kerf **width** separately in the WEDM process. To obtain optimum parameters combination for maximization of MRR and SF, Taguchi's experimental design method is used. Sarcar et al [7] optimized the trim cutting operation of WEDM of γ-TiAl alloy for a given machining conditions by desirability function approach. Response Surface Methodology (RSM) was used to develop a prediction model of surface roughness for machining mild steel. Puri and Bhattacharya [8] performed analysis of wire- tool vibration inorder to achieve a high precision and accuracy in WEDM with the system equation based on the force acting on the wire in a multiple discharge process.

EXPERIMENTAL SET UP

The Al6061 material is reinforced with MoS2 powder of 2 micron particle size with 4% weight ratio of 5 mm thickness was prepared by stir casting technique. Machining of the same MMC work pieces are performed on Electronica - make 4 - axis CNC SPRINTCUT wire electrical discharge machine (fig.2). De-ionized water is used as dielectric fluid and brass wire of 0.25mm diameter is used as electrode.

Figure 2: Photograph of experimental set up

The following parameters selected as pre setting on the machine.

Machine	: SPRINTCUT
Dielectric	: De-ionized water
Wire material	: Brass
Wire tension	: 70N
Wire velocity	: 3 m/min
Gap voltage	: 80 Volts
Wire diameter	: 0.25 mm

Figure 3: Profile Projector

The work piece was machined in the shape of ' L' for measuring the spark gap and corner radius by Profile Projector (fig.3). A rectangular piece has been cut for checking surface roughness value as shown in fig.4

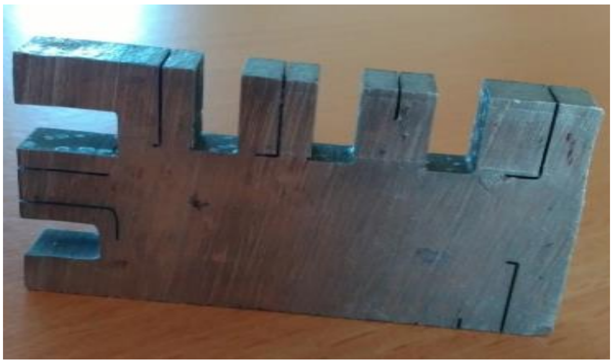

Figure 4: Machined work piece

Product quality obtained by the WEDM is always affected by the machining parameters like peak current, pulse on time, pulse off time, and wire feed. Proper selection of machining parameters can cause higher material removal rate and lower surface roughness. In the present work, Taguchi method, a powerful tool for parameter design of performance characteristics, was used based on L9 orthogonal array. The parameters selected for different settings of pulse on time, pulse off time, peak current and wire feed were used in the experiments were shown in table 1.

Table 1: Machining parameters and their factor levels used in the experiments

Parameter	Units	Level		
		L1	L2	L3
Pulse on time (T_{on})	µs	6	8	10
Pulse off time T_{on})	µs	4	5	6
Peak current (I_p)	A	4	3	2
Wire feed (W_F)	mm/min	1	2	3

Table 2: Experimental design using Taguchi L9 orthogonal array

Exp No.	Factor assignment			
	T_{on} (µs)	T_{off} (µs)	I_p A	W_F mm/min
1	6	4	4	1
2	6	5	3	2
3	6	6	2	3
4	8	4	3	3
5	8	5	2	1
6	8	6	4	2
7	10	4	2	2
8	10	5	4	3
9	10	6	3	1

Process characterization is made by using ANOVA to identify the key input variables that affect SR and MRR. The cutting width is measured on L cut with Profile Projector (fig 4). The Surface roughness measurements are done using surface roughness tester. The spark gap is calculated from cutting width.

Cutting width, W = d + 2 x Sg, where d is the diameter and Sg is the spark gap.

The MRR is calculated as, MRR = CS * W * T, Where 'CS' is the cutting speed.

The S / N Ratio η can be calculated as shown below:

$$\eta = -10\log\left(\frac{1}{n}\sum_{i=1}^{n} Y_{SR}^2\right)$$

RESULTS AND DISCUSSIONS

The effect of machining parameters on material removal rate and surface roughness in machining Al 6061/MoS2 MMC are studied. The results from the experimental plan of MRR and Ra are shown in table 3. In order to analyze the results of the experimental runs, analysis of variance (ANOVA) was utilized to examine the influence of cutting parameters of WEDM on the MRR and Ra . The ANOVA was executed and the results are shown in tables 4 to 7.

Table 3: Experimental results and S/N ratios of SR and MRR

Exp. NO	Factor Assignment				SR (µm)	S/N Ratio	MRR (mm^3/min)	S/N Ratio
	Ton (µs)	T_{off} (µs)	I_p A	W_F mm/min				
1	6	4	4	1	3.8	-11.59	8.82	-18.91
2	6	5	3	2	3.6	-11.12	8.42	-18.51
3	6	6	2	3	4.2	-12.46	9.05	-19.13
4	8	4	3	3	3.8	-11.59	9.15	-19.23
5	8	5	2	1	4.2	-12.46	7.51	-17.51
6	8	6	4	2	3.5	-10.88	6.83	-16.69
7	10	4	2	2	3.09	-9.79	8.66	-18.75
8	10	5	4	3	4.06	-12.17	8.28	-18.36
9	10	6	3	1	3.56	-11.02	9.43	-19.49

Table 3 shows the orthogonal array based experimental results of material removal rate and the surface roughness. The table 5 and table 7 lists the corresponding ANOVA results for MRR and SR, where the contribution of each parameter was calculated. From the table 5 it is found that the pulse- on time dominates the performance characteristics of material removal rate, , contributing to almost 33% followed by the Peak current (29%). From the table 7 it is found that the Wire feed plays a major contribution of 59% in Surface roughness.

The data reflects that the pulse-on time , peak current are the influencing parameters on MRR, wire feed rate on surface roughness. These values must be optimal for effective machining with WEDM of any material and of any size.

Material removal rate

Table 4: Response Table for S/N ratio of MRR

Control factor	Mean n by factor level		
	1-Mean (L1)	2-Mean (L2)	3-Mean (L3)
TON (µs)	-18.8537	-17.8149	-18.8722
TOFF (µs)	-18.9674	-18.1334	-18.440
I_P (A)	-17.9923	-19.0798	-18.4687
W_F (mm/min)	-18.6412	-17.9883	-18.9113

Table 5: Result of ANOVA for MRR

Process parameter	DOF	SS	V	CONTRIBUTION %
TON	2	2.1970	1.0985	34.33
TOFF	2	1.0674	0.5337	16.68
I_P	2	1.7830	0.8915	27.867
W_F	2	1.3507	0.6753	21.11

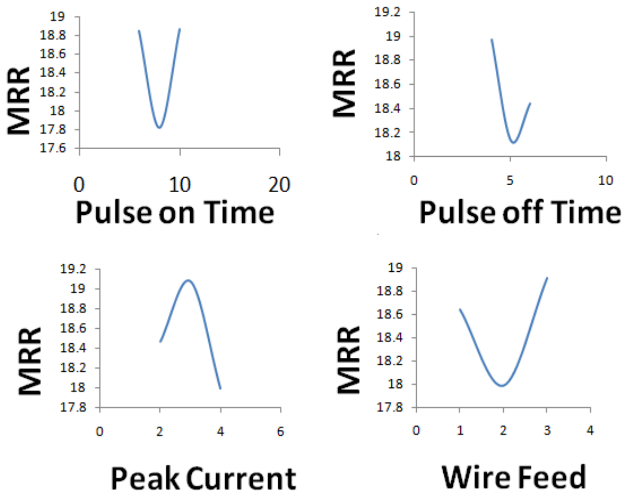

Figure 5: Factor effects on S/N ratio for MRR

Surface Roughness

Table 6: Response Table for S/N ratio of SR

Control factor	Mean n by factor level		
	1-Mean (L1)	2-Mean (L2)	3-Mean (L3)
TON (µs)	-11.7288	-11.6472	-10.9992
TOFF (µs)	-10.9967	-11.9204	-11.4580
I_P (A)	-11.5491	-11.2498	-11.5763
W_F (mm/min)	-11.6961	-10.602	-12.077

Table 7: Result of ANOVA for the surface roughness (Ra)

Process parameter	DOF	SS	V	CONTRIBUTION %
TON	2	0.9586	0.4793	16.10
TOFF	2	1.2795	0.6397	21.494
I_P	2	0.1969	0.0984	3.307
W_F	2	3.5176	1.7588	59.09

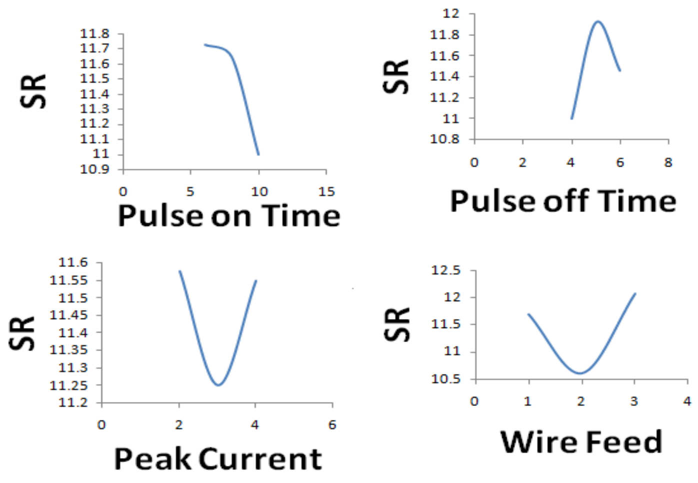

Figure 6: Factor effects on S/N ratio for SR

The mean factor levels were determined and the corresponding levels were identified. The parameters related to the corresponding levels are identified as optimum values. These values are listed below.

Process parameter	Optimum value	CONTRIBUTION (%) on MRR	CONTRIBUTION (%) on SR
TON	10	32.51	14.91
TOFF	6	17.67	21.486
I_P	3	28.69	4.783
W_F	1	21.11	58.814

CONCLUSIONS

Influence of Wire EDM machining parameters on surface roughness of Al 6061/ MoS2 MMC with 4% weight ratio were investigated in this paper. The machining parameters included pulse – on time, pulse – off time, peak current, and wire feed were found to have much impact on surface roughness and MRR and were optimized. The parameters affecting the material removal rate and surface roughness were identified using ANOVA technique. It is also observed that the wire feed and pulse – off time were significant variables for Surface roughness and pulse-on time and peak current were for the MRR.

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