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Experimental Investigation of Wire EDM Process Parameteres on Aluminium Metal Matrix Composite Al2024/SiC

Ashish Srivastava, Amit Rai Dixit** and, Sandeep Tiwari****

ABSTRACT

Surface finish and Metal removal rate (MRR) is one of the most prime requirement of customer and it is also a significant tool to reduce the cycle time of any machine operation as well as the overall cost of the production. In the recent years, quality of product is a essential demand of customer which turned to the fast and rapid technologies of production. This paper presents an experimental study on composite of Al2024 reinforced with SiC to investigate the effects of electric discharge machining(EDM) for three levels of each parameters such as current ,pulse on time and reinforcement percentage on surface finish and MRR. Response surface methodology (RSM) technique has been applied to optimize the machining parameters for minimum surface roughness and maximum MRR.

Keywords: *Metal Matrix Composite; Al2024; Wire EDM; RSM.*

1.0 Introduction

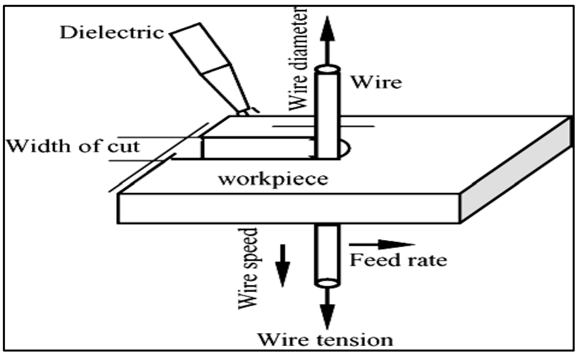
In the modern era of science and technology the demand for the precise engineering products has became the vital manufacturing sector to produce dimensionally accurate product .From the past research and experiment it has been explained that surface roughness has a great impact on the functioning of the machined parts [1,2]. The properties such as corrosion resistance, fatigue resistance, load bearing capacity, noise reduction, are influenced by the surface roughness. Several manufacturing process such as casting, powder metallurgy, hot working uses the integration of man, machine and material which suffers the surface irregularities due to error. Whatever may be the manufacturing process used, it is not possible to produce perfectly smooth surface. The imperfection and irregularities are to bind to occur. However optimum process and its parameter can be utilised to overcome irregularities to a great extent. In regard to better surface finish and the surface roughness and metal removal rate, the selection of proper combination of machining variables is required [2]. Wire electrical discharge machining (WEDM) has become an important non-traditional machining process in the recent years and it is widely used in the aerospace and automotive industry [3]. It has the ability to machine precise, complex and irregular shapes through difficult to machine components. Furthermore, the high degree of accuracy and the fine resultant surface finish make WEDM valuable. Recently, WEDM is being used to machine a wide variety of miniature and micro-parts from metals, alloys, sintered materials, cemented carbides, ceramics and silicon [4–6].

2.0 Experimental Procedures

Figure 1 shows the schematic diagram of the WEDM process. It is an advanced material removal process using a thin copper wire as the tool electrode.The workpiece and electrode are separated by dielectric medium (kerosene–deionized water). The travelling of the wire, in a closely controlled manner, through the workpiece, generates spark discharges and then erodes the workpiece to produce the desired shape (based on the path of the tool electrode).

**Corresponding Author: Department of Mechanical Engineering, Indian School of Mines, Dhanbad, India*
(E-mail: ashish7185@gmail.com)
***Department of Mechanical Engineering, Indian School of Mines, Dhanbad, India*
****Department of Mechanical and Automation Engineering, ASET, Amity University, G. B. Nagar, India*

Fig 1: Wire-EDM Process [6]



In the present work, the statically data has been made and analyzed to predict the surface roughness and MRR with the help of Response Surface Method (RSM) and design of experiment. Implementation of RSM (Response Surface Method) methodology is practically accurate and easy. By Response Surface Method, optimisation procedure is selected to optimize the output response, surface roughness and metal removal rate of work [7].

2.1 Work material

The work material used under study is Al-2024. This alloy has copper as the primary alloying element. The composition of Al-2024 include 4.4% copper, 0.6% manganese, 1.4% magnesium and less half percent of silicon, zinc, nickel, chromium, lead and bismuth. Al-2024 has density of 2.78 gm/cm3 and young modulus as 73 GPa [8-10]. It is wieldable only frictional welding and has average mach inability. It has poor corrosion resistance. Al-2024 finds its application in aircraft structure, especially wings, shear web and ribs and structural areas where stiffness, fatigue, performance and good strength are required [11-13].

2.2 Methodology

Wire EDM Machining and Response Surface Methodology (RSM) is used to describes the effect of parameters on Composite Material.

2.2.1 Response surface methodology (RSM)

Response Surface Methodology is combination of mathematical and statistical technique, used to develop the mathematical model for analysis and optimization **[14-15].** By conducting experiment trails and applying the regression analysis, the output responses can be expressed in terms of input machining parameters namely table speed, depth of cut and spindle speed. The major steps in Response Surface Methodology are:

1. Identification of predominate factors which influences the surface roughness.
2. Developing the experimental design matrix, conducting the experiments as per the above design matrix.
3. Developing the mathematical model.
4. Determination of constant coefficients of the developed model.
5. Testing the significance of the coefficients.
6. Adequacy test for the developed model by using analysis of variance (ANNOVA).
7. Analyzing the effect of input machining parameters on output responses, surface roughness and MRR. [15].

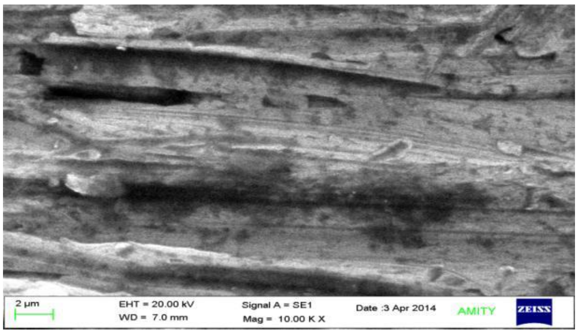
3.0 Micro Structural Observation

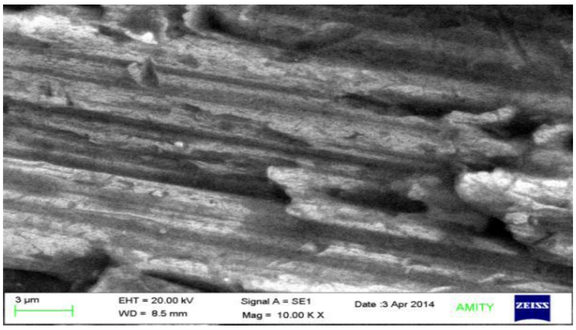
For most applications, a homogeneous distribution of the particles is desirable in order to maximize the mechanical properties. Sample for micro structural analysis is prepared by means of a polisher machine and different types of grit papers. Samples are finished up to the mirror polished shine and then clean by keller's reagent chemical solution. Scanning electron Microscopy (SEM) test has been carried out to check the microstructure at two levels at before machining and after machining.

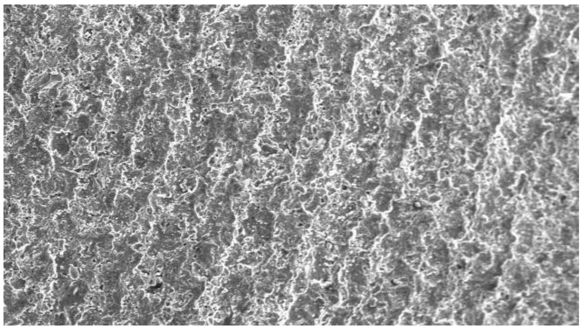
3.1 Scanning electron microscopy (SEM) test

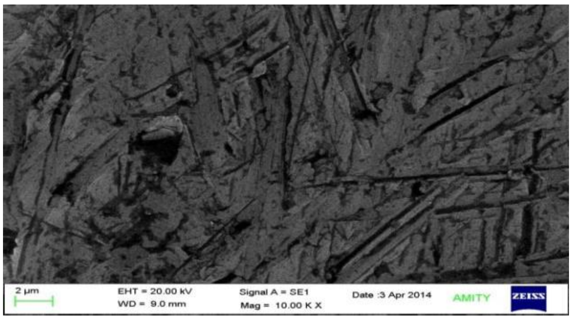
This test is done to check the homogeneity of the casting and the defects in the casting. The SEM of all the

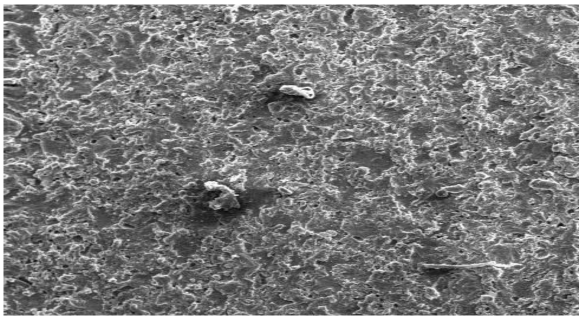
Fig 2: SEM Image of (a) Al2024+ 2%SiC (b) Al2024+ 4%SiC (c) Al2024+ 6%SiC









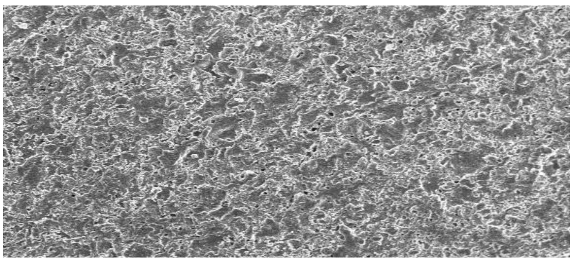


specimens were observed and it was seen that the reinforcement was thoroughly mixed with the matrix metal, and hence homogeneity was achieved. Some defects like porosity were also seen but they tend to insignificant**.**

3.2 Scanning electron microscopy (SEM) test of machined part

The test was done to check the structure of surface finish of the sample after the machining by a non-conventional process that is Wire Electron Discharge Machine. From these images it was observed that the surface finish that an non-conventional machining process give is better than the surface finish we get from the conventional machining process.

Fig 3: SEM image of Machined Part of (a) Al2024+ 2%SiC (b) Al2024+ 4%SiC (c) Al2024+ 6%SiC



4.0 Results and Discussion

The following matrix shown in table 1 is used as a level of design for the machining analysis.

Table 1: Level of Design

Parameter	Peak current	Pulse on time	Reinforcement %
Unit	A	µS	%
SYMBOL	A	B	C
Level1	2	15	2
Level2	3	20	3
Level3	4	25	4

Results are coming out by applying the response surface methodology. This approach is the procedure for determining the relationship between various process parameters with the various machining criteria and exploring the effect of these process parameters on the coupled responses. The following table 2 shows the design matrix of RSM.

The below table describes the design matrix of input and output. There are total 17 randomly designed runs are created and there corresponding output are shown in table. ANOVA responses of the study for surface roughness are shown in table 3.

The Model F-value of 93.88 implies the model is significant. There is only a 0.01% chance that a "Model F-Value" this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case A, B, C are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model.

Table 2: Design Matrix of Response Surface Methodology (RSM)

Std	Run	Block	Factor 1 A:PEAK CURR A	Factor 2 B:PULSE ON T S	Factor 3 C:% REINFORC %	Response 1 SURFACE ROU Ra	Response 2 MRR mm/min
9	1	Block 1	2.00	1.00	1.00	2.433	1.3935
5	2	Block 1	1.00	2.00	1.00	2.31	1.2864
11	3	Block 1	2.00	1.00	3.00	2.687	1.3546
3	4	Block 1	1.00	3.00	2.00	2.4817	1.3953
14	5	Block 1	2.00	2.00	2.00	2.6137	1.4761
2	6	Block 1	3.00	1.00	2.00	2.7693	1.5338
10	7	Block 1	2.00	3.00	1.00	2.576	1.451
12	8	Block 1	2.00	3.00	3.00	2.813	1.435
17	9	Block 1	2.00	2.00	2.00	2.6137	1.4761
4	10	Block 1	3.00	3.00	2.00	3.1017	1.6476
13	11	Block 1	2.00	2.00	2.00	2.6137	1.4761
1	12	Block 1	1.00	1.00	2.00	2.206	1.3094
16	13	Block 1	2.00	2.00	2.00	2.6137	1.4761
7	14	Block 1	1.00	2.00	3.00	2.5483	1.3137
8	15	Block 1	3.00	2.00	3.00	3.0393	1.512
15	16	Block 1	2.00	2.00	2.00	2.6137	1.4761
6	17	Block 1	3.00	2.00	1.00	2.898	1.5574

Table 3: ANOVA Table by the Response Surface Methodology for Surface Roughness

Response 1 SURFACE ROUGHNESS

ANOVA for Response Surface Linear Model

Analysis of variance table [Partial sum of squares - Type III]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	0.83	3	0.28	93.88	< 0.0001	significant
A-PEAK CURRE	*0.64*	*1*	*0.64*	*216.92*	*< 0.0001*	
B-PULSE ON TI	*0.096*	*1*	*0.096*	*32.61*	*< 0.0001*	
C-% REINFOR(	*0.095*	*1*	*0.095*	*32.12*	*< 0.0001*	
Residual	0.038	13	2.949E-003			
Lack of Fit	*0.038*	*9*	*4.260E-003*			
Pure Error	*0.000*	*4*	*0.000*			
Cor Total	0.87	16				

4.1 Effects of various parameters on surface roughness

Fig 4: Effect of Peak Current on Surface Roughness

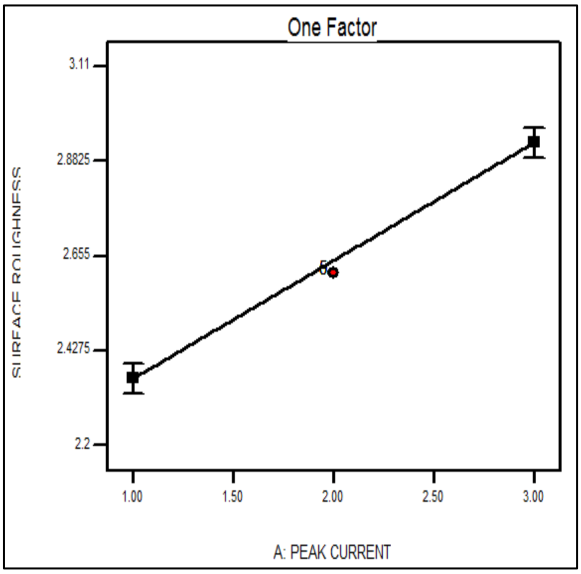


Figure 4 shows the graph between surface roughness and peak current, as the graph indicates that while increasing the peak current, roughness will be increases.

Fig 5: Effect of Pulse on Time on Surface Roughness

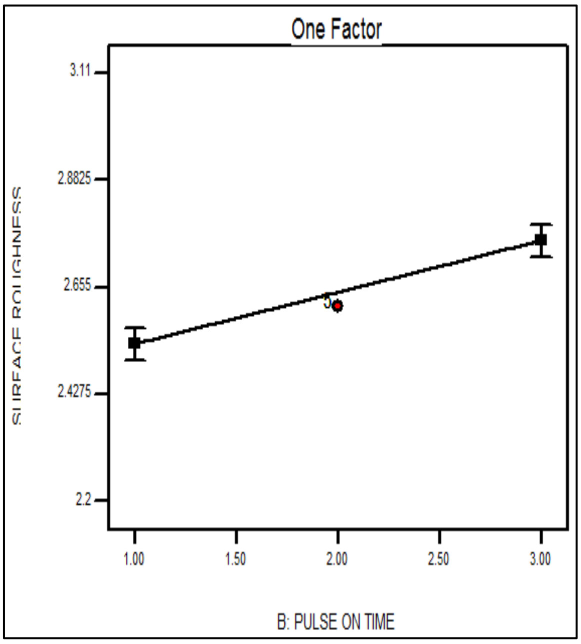


Figure 5 shows the graph between surface roughness and Pulse on time, as the graph indicates that while increasing the peak Pulse on time, roughness will be increases.

Fig 6: Effect of Reinforcement on Surface Roughness

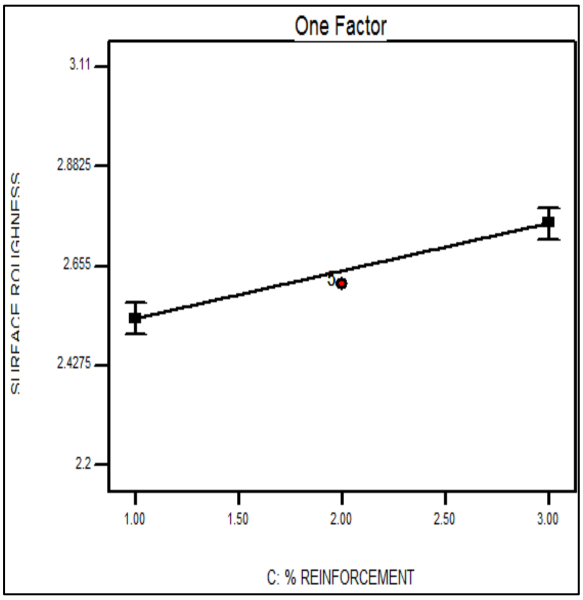


Figure 6 shows the graph between surface roughness and % of reinforcement, as the graph indicates that while increasing the reinforcement %, roughness will be increases.

4.2 Effects of various parameters on material removal rate (MRR)

ANOVA responses of the study for surface roughness are shown in table 4. The Model F-value of 171.91 implies the model is significant.

There is only a 0.01% chance that a "Model F-Value" this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case A, B, C, AC, C2 are significant model terms.

Values greater than 0.1000 indicate the model terms are not significant.

If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model.

Table 4: ANOVA Table by the Response Surface Methodology for Surface Roughness

Response 2 MRR

ANOVA for Response Surface Quadratic Model

Analysis of variance table [Partial sum of squares - Type III]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	0.14	9	0.016	171.91	< 0.0001	significant
A-PEAK CURRE	*0.11*	*1*	*0.11*	*1198.19*	*< 0.0001*	
B-PULSE ON TI	*0.014*	*1*	*0.014*	*152.60*	*< 0.0001*	
C-% REINFOR(	*6.661E-004*	*1*	*6.661E-004*	*7.13*	*0.0319*	
AB	*1.946E-004*	*1*	*1.946E-004*	*2.08*	*0.1920*	
AC	*1.321E-003*	*1*	*1.321E-003*	*14.15*	*0.0071*	
BC	*1.311E-004*	*1*	*1.311E-004*	*1.40*	*0.2747*	
A^2	*1.924E-005*	*1*	*1.924E-005*	*0.21*	*0.6636*	
B^2	*1.897E-004*	*1*	*1.897E-004*	*2.03*	*0.1970*	
C^2	*0.016*	*1*	*0.016*	*167.06*	*< 0.0001*	
Residual	6.535E-004	7	9.336E-005			
Lack of Fit	*6.535E-004*	*3*	*2.178E-004*			

Fig 7: Effect of Peak Current on MRR

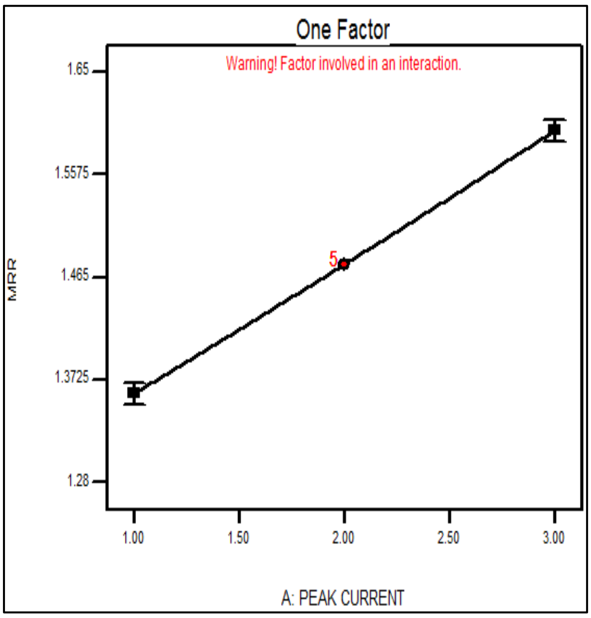


Figure 7 shows the graph between MRR and peak current, as the graph indicates that while increasing the peak current, MRR will be increases.

Fig 8: Effect of Pulse on Time on MRR

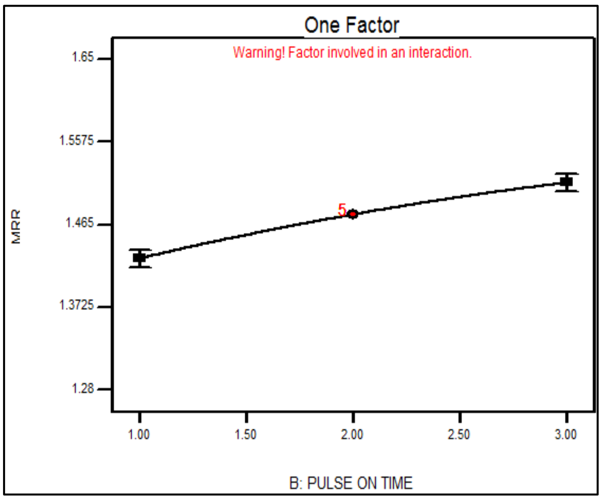


Figure 8 shows the graph between MRR and Pulse on time, as the graph indicates that while increasing the Pulse on time, MRR will be increases.

Fig 9: Effect of % Reinforcement on MRR

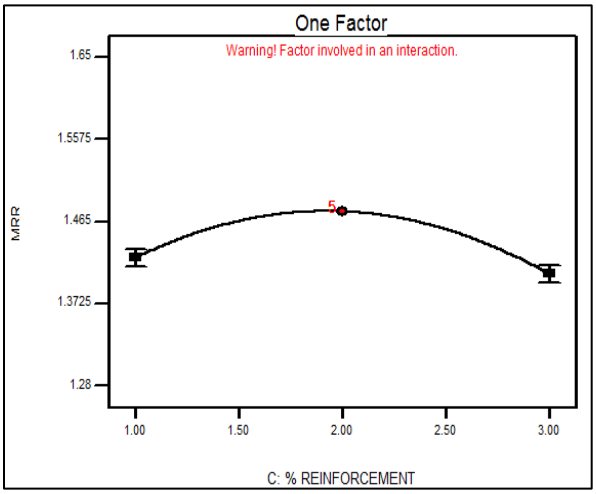


Figure 9 shows the graph between MRR and Reinforcement %, as the graph indicates that while increasing the Reinforcement %, MRR will be increases initially and then decreases.

5.0 Conclusion

The current study was done to study the effect of machining parameters on the surface roughness. The following conclusions are drawn from the study:

1. The SEM of all the specimens was observed and it was seen that the reinforcement was thoroughly mixed with the matrix metal, and hence homogeneity was achieved.
2. It was found that aluminium, silicon, oxygen and carbon are in significant amount and SiC as the reinforcement.
3. From the SEM images of machined samples it was observed that the surface finish that an non- conventional machining process give is better than the surface finish we get from the conventional machining process.
4. From ANOVA analysis we got that parameters considered by us have given significant result both for Surface roughness and Material removal rate.
5. Surface roughness is increases with the increase in peak current.
6. Surface roughness is increases with the increase in Pulse on time.
7. Surface roughness is increases with the increase in % reinforcement.
8. Material removal rate is increased with the increase in Peak current.
9. Material removal rate is increased with the increase in Pulse on time.
10. Material removal rate is decreased with the increase in % reinforcement.

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