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Experimental Analysis of Wire EDM Process Parameters on Composite Aluminum Metal Matrix Al2024/SiC

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Metal Matrix Composite,Al2024, Wire EDM,RSM

Abstract
One of the most important client requirements is surface finish and metal removal rate (MRR), which is also a key tool for cutting the cycle time of any machine operation and the overall cost of production. In recent years, customers have prioritised product quality over speed and efficiency of production as key demands. In order to examine the impacts of electric discharge machining (EDM) for three levels of each parameter, such as current, pulse on time, and reinforcing percentage on surface finish and MRR, this research offers an experimental study on a composite of Al2024 reinforced with SiC. In order to maximise MRR and minimise surface roughness, the response surface methodology (RSM) technique has been used to optimise the machining parameters.

1. Introduction

The need for precision engineering products has grown to be a crucial manufacturing industry to develop dimensionally accurate items in the modern era of science and technology. Surface roughness has a significant impact on how well machined parts work, according to previous research and experimentation [1,2]. Surface roughness has an impact on qualities including noise reduction, load bearing capacity, corrosion resistance, and fatigue resistance. Several manufacturing processes, including casting, powder metallurgy, and hot working, integrate people, machines, and materials; yet, these processes can result in surface imperfections as a result of human mistake. No matter what manufacturing method is employed, a flawlessly smooth surface cannot be created. The flaws and anomalies are bound to happen.

But, anomalies can be greatly reduced by using the best procedure and its parameters. The right mix of machining factors must be chosen in order to get a superior surface smoothness, reduce surface roughness, and increase metal removal rate [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. 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).

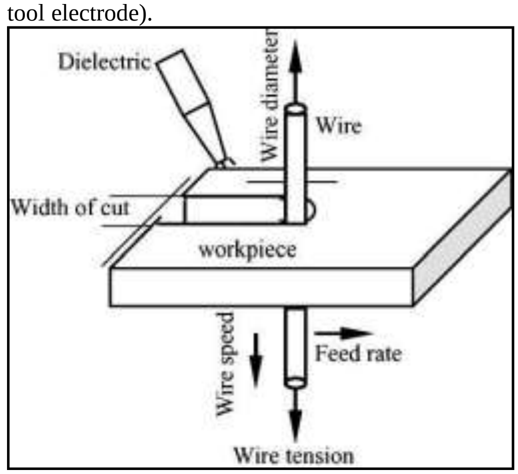

Fig: 1. Wire-EDM process [6]

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].

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

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[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 arerequired [11-13].

Methodology

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

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:

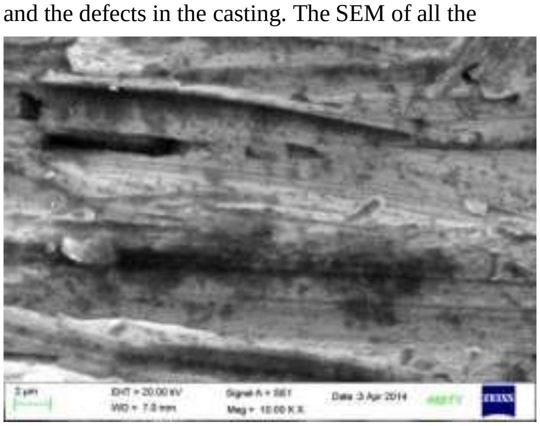
1. Identification of predominate factors which influences the surface roughness.
2. Developing the experimental design matrix, conducting the experiments as per the above design matrix.
3. Developing the mathematical model.
4. Determination of constant coefficients of the developed model.
5. Testing 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].

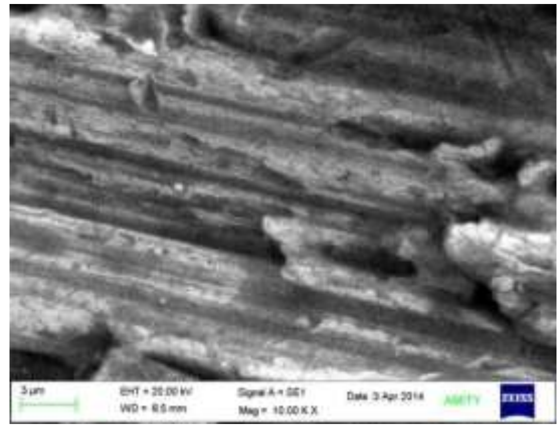
3. Micro structural Observation

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.

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





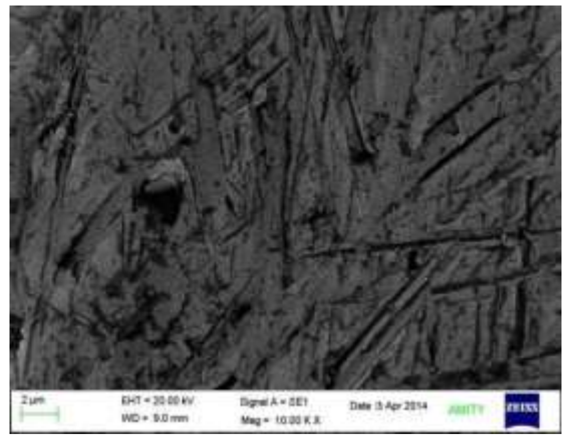
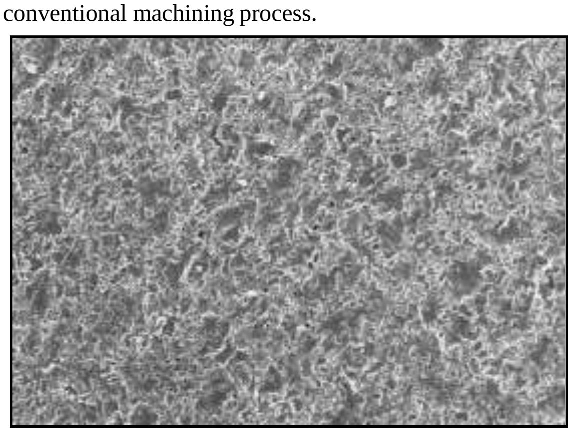


Fig: 2. SEM image of (a) Al2024+ 2%SiC (b) Al2024+4%SiC (c) Al2024+ 6%SiC

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**.**

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.



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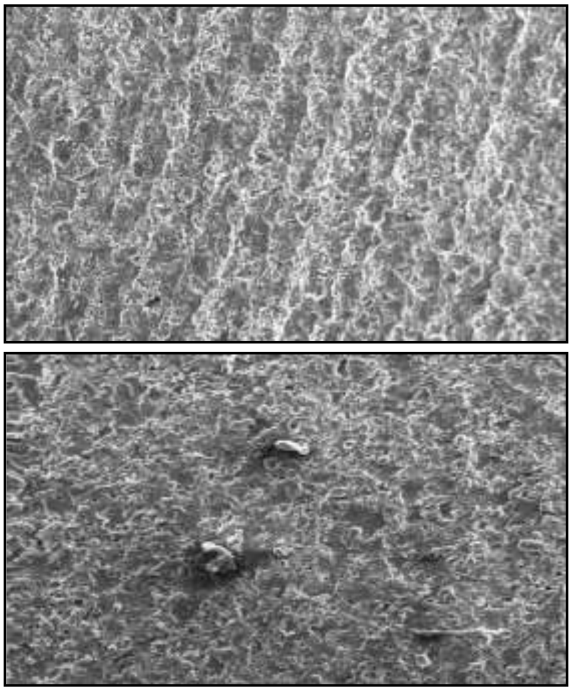

Fig: 3. SEM image of Machined Part of (a) Al2024+ 2%SiC (b) Al2024+ 4%SiC (c) Al2024+ 6%SiC

4. 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	3.1617	1.6470
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				

Effects of various parameters on SurfaceRoughness

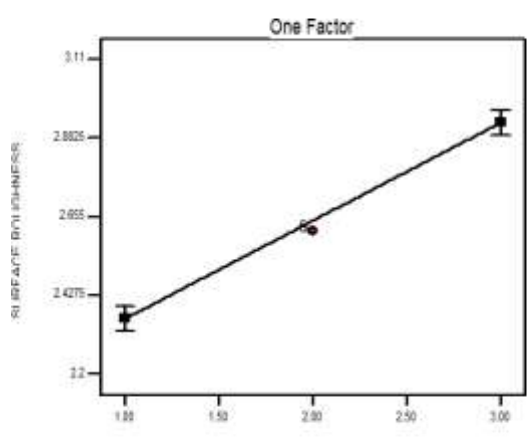

Fig. 4. Effect of peak current on Surface Roughness Figure 4 shows the graph between surface roughness and peak current, as the graph indicates that whileincreasing the peak current, roughness will be increases.

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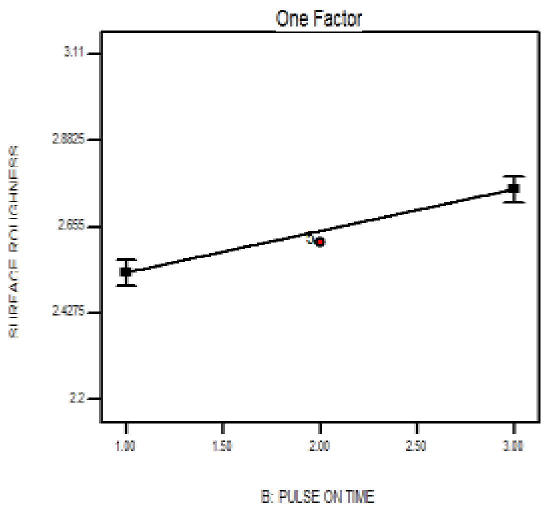

Fig: 5. Effect of Pulse on time on Surface Roughness Figure 5 shows the graph between surface roughness and Pulse on time, as the graph indicates that while increasing the peak Pulse on time, roughness will be increases.

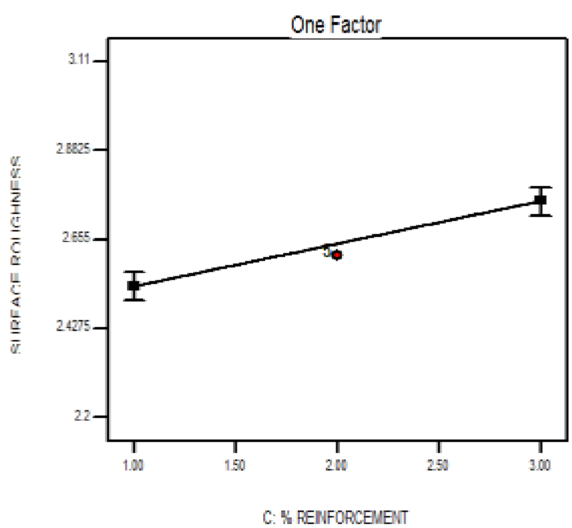

Fig: 6. Effect of Reinforcement on Surface Roughness

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

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, C^2 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.

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Table: 4. ANOVA Table by the Response SurfaceMethodology 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-% REINFORI	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			

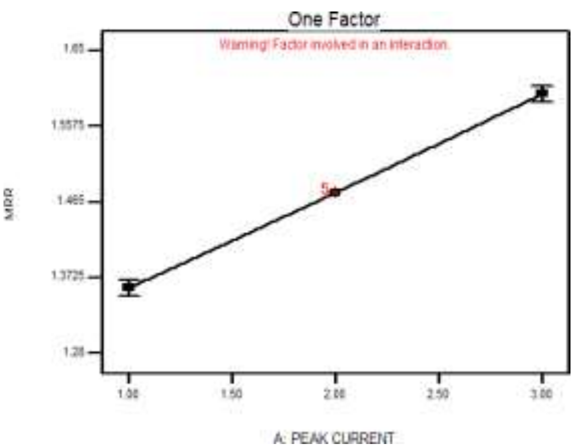

Fig: 7. Effect of peak current on MRR

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

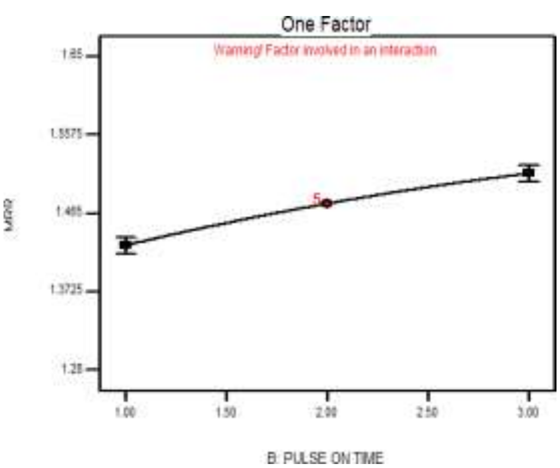

Fig: 8. Effect of Pulse on time on MRR

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.

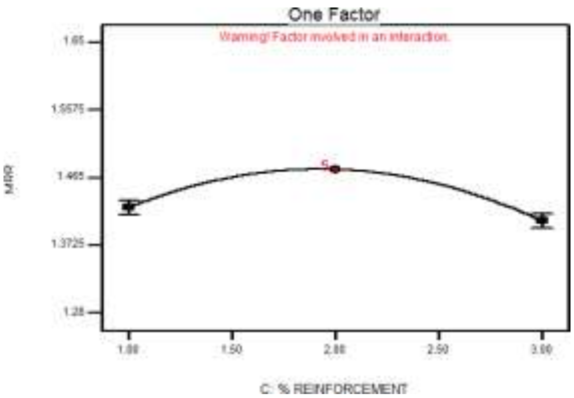

Fig: 9. Effect of % Reinforcement on MRR

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. Conclusion

The goal of the current study was to determine how different machining parameters affected surface roughness. The study's findings lead to the following interpretations:

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 inpeak current.
6. Surface roughness is increases with the increase inPulse on time.
7. Surface roughness is increases with the increase in %reinforcement.
8. Material removal rate is increased with the increase inPeak current.
9. Material removal rate is increased with the increase inPulse on time.
10. Material removal rate is decreased with the increase in % reinforcement.

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