Experimental Investigation and Optimization of Machinability Characteristics of Wire EDM Machining of Al6061/20%SiC Composite

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ABSTRACT: ***The machinability of the Al6061/20%SiC metal matrix composite during wire EDM was investigated. The present work is to optimize the wire EDM process parameters of Al6061 matrix reinforced with 20 wt.% SiC fabricated through the casting processes. The machining parameters such as current, voltage, pulse on time and pulse off time are optimized using L9 orthogonal array with multi-response considerations namely material removal rate and surface roughness. The L9 DOE results indicated that the increase in input current increases the material removal rate. Similarly the minimum surface roughness was found at maximum input voltage and lower input current condition.***

KEYWORDS: Al/SiC composites, Mechanical properties, WEDM Machining, Surface finish, Surface roughness.

1. INTRODUCTION

Aluminum alloys are the best choices for structural applications as it possess high specific strength, rigidity and modulus at elevated temperatures. However, the material properties need to be improved while going for the advanced structural applications. There are several research attempts were made for the improvement of the material properties among all the metal matrix composites (MMS) shows as most promising technique. The recent developments on MMC prove that incorporation of silicon carbide (SiC) particles enhances the metallurgical, tribological as well as mechanical properties like hardness, wear resistance and toughness. The machinability studies on MMC revealed that the proper selection of proper cutting tool plays a vital role. The surface roughness of the machined surface again mainly depends on the cutting speed and feed. The better surface finish on MMC is possible with higher cutting speed and low feed rate [1]. Manna and Bhattacharayya investigated the machinability of SiC particulate Al MMC during turning operation. The investigation proved that the built-up edges (BUEs) were formed while machining the material with high speed and lower depth of cut. Also their work proved that their machining tool was better than other tools like PCD [2, 3] and CBN [4]. In similar fashion, the influence of SiC reinforced ratios in MMC was examined and reported by few researchers. It was reported that the mechanical properties like toughness and hardness of the Al was improved with respect to increase in reinforcement ratio. However, the tensile property was greatly affected and resulted with different trend [5].

The dielectric medium chosen for the EDM plays an energetic role during the machining of Al/SiC MMC. The addition of tungsten power in the kerosene dielectric fluid significantly improved the material removal rate compared to kerosene dielectric fluid. It also helped to obtain a reduced recast layer thickness with improved surface finish [6, 7]. The power consumption during the machining process has to be addressed appropriate along with the tool life. Design of experiments (DOE) is one such tool used to accomplish the above objective. The DOE helps to obtain the desirability values for the machining process parameters through desirable functional analysis [8]. Optimization of machining process parameters greatly influences the final output responses. The techniques like grey relational analysis (GRA) and analysis of variance (ANOVA) were used by many researchers in recent times for optimizing the Wire EDM machining of MMCs [9-11]. Based on the inputs received from the previous research works, the present experimental investigation is mainly focused on Al6061 20 wt.% SiC aluminum MMC machinability studies for improved material removal rate and surface roughness.

2. EXPERIMENTAL SETUP

The experimental studies were performed on ELECTRONICA WEDM machine .Various input parameters varied during the experimentation are pulse on time (TON), pulse off time (TOFF), servo voltage (SV),peak current (IP). The effects of these input parameters are studied on material removal rate using one factor at a time approach. The units of some input parameters such as wire tension, pulse on time, pulse off time, servo feed etc. are taken as per the machine setting. WEDM machine tool Different settings of pulse duration, open circuit voltage, and dielectric flushing pressure were used in the experiments. During all experiments, two input variables flushing pressure (WP) and peak voltage (VP) were kept constant.

Table 1. Machine Specification

Description	Details
Machine make	Electronica
Vertical axis movement (mm)	200
Horizontal axis movement (mm)	400
Wire used & Diameter (mm)	Copper wire & 0.25
Motor rating	3 phase, 430 V
Dielectric fluid	De mineralized water

The value of WP is fixed to1 unit (15 kg/cm2) and value of VP is fixed to 2 units. The machine specification details are given in the Table 1.In each experiment one input variable was varied while keeping all other input variables at some mean fixed value and the effect of change of the input variable on the output characteristic i.e. material removal rate is studied and reported in this paper.

6061 aluminum silicon carbide composite was taken as work piece material for machining of 12 mm dia.

Brass wire with 0.25 diameter (900 N/mm2 tensile strength) was used in the experiments. Mineral water was used as dielectric fluid. During the experiments 12 mm rod was cut to two pieces To evaluate the effects of machining parameters on performance characteristic (MRR), roughness value and to identify the performance characteristic under the optimal machining parameters, a specially designed experimental procedure is required.

2.1 Design of experiment

Design of Experiments (DOE) refers to planning, designing and analyzing an experiment so that valid and objective conclusions can be drawn effectively and efficiently. In performing a designed experiment, changes are made to the input variables and the corresponding changes in the output variables are observed. The input variables are called factors and the output variables are called response. Factors may be either qualitative or quantitative. Qualitative factors are discrete in nature (such as type of material, color of sample). Each factor can take several values during the experiment.

Each such value of the factor is called a level. A trial or run is a certain combination of factor levels whose effect on the output is of interest. It is convenient to represent the high level value of a factor as +1 and the low level value as -1, and transforming all the factors into the same [-1 1] coded range. It is essential to incorporate statistical data analysis methods in the experimental design in order to draw statistically sound conclusions from the experiment. Some of the advantages of DOE over One-Variable-At-a-Time approach (OVAT) are that a DOE approach enables to separate the important factors from the unimportant ones by comparing the factor effects. Also, interaction effects among different factors can be studied through designed experiments. For design the experiments, certain elements such as number of run, replication, randomization and centre point must be taken into consideration. Since we have two levels and four factor. The operating parameter ranges and L9 orthogonal array is listed in Table 2 and 3 respectively.

Table 2. Operating parameters ranges

Factors	Parameters	Low	Medium	High
A	Current (A)	1	2	3
B	Voltage (V)	40	50	60
C	Pulse – on time(μs)	4	5	6
D	Pulse - off time(μs)	6	8	10

Table 3. L_9 orthogonal array

Run	Current (A)	Voltage (V)	P On Time (μs)	P Off Time (μs)	MRR (mm^3/min)	Ra (μs)
1	2	40	5	10	0.08	5.47
2	3	50	4	10	0.07	3.50
3	2	60	4	8	0.06	4.14
4	1	60	6	10	0.1	5.30
5	3	60	5	6	0.04	5.43
6	3	40	6	8	0.11	3.97
7	2	50	6	6	0.1	5.08
8	1	40	4	6	0.06	3.83
9	1	50	5	8	0.06	3.47

3. RESULTS AND DISCUSSION

The experiments were conducted based on the set of parameters derived through L9 orthogonal array. The experimental outcomes were discussed in the following section.

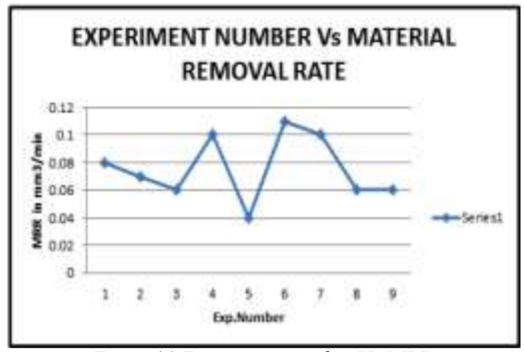
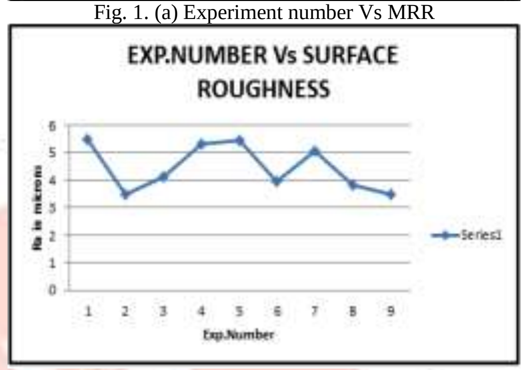


Fig. 1. (a) Experiment number Vs MRR



(b) Experiment number Vs SR

The Fig. 1 shows the graphs constructed with respect to Experiment number Vs MRR and Experiment number Vs SR. The maximum material rate is obtained in the 6th experiments. And its corresponding parameters values are Current-3 amps.; Voltage – 40 Volts; Pulse on time -6 microseconds & Pulse off time – 8 Micro seconds. Similarly, the minimum surface roughness is 3.47 Ra observed in the 9th experiments. And its corresponding parameters values are Current of 1amps.; Voltage –50 Volts; Pulse on time - 5 microseconds & Pulse off time – 8 Micro seconds.

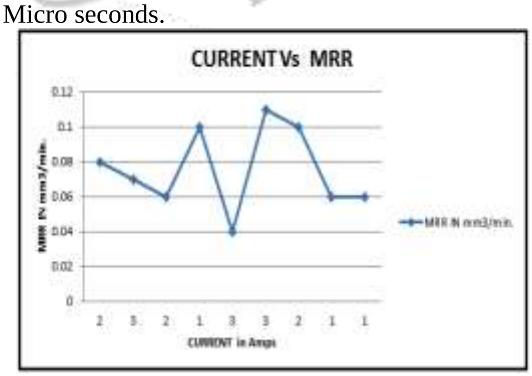


Fig. 2. (a) Current Vs MRR

(b) Current Vs SR

The Fig. 2 shows the graphs constructed with respect to Current Vs MRR and Current Vs SR. It is noted that maximum material is removed due to increase of current. From the figure the material removal rate is maximum at Exp no.6. Similarly the surface roughness value is obtained minimum at experiment No.9 and the current value is 1A. The Fig. 3 shows the graphs constructed with respect to Voltage Vs MRR and Voltage Vs SR. It is observed from the figure that the material removal rate is obtained maximum at Exp.No. 6 and the voltage is at 40V. Similarly, the minimum surface roughness value is obtained at experiment No.2&9 and the voltage is at 50V. The graphs constructed with respect to Pulse on time Vs MRR and Pulse on time Vs SR are illustrated in the figure 4. It indicates that the maximum material removal rate is obtained at Experiment No.6 and the pulse on time of 6 micro seconds. Also the minimum surface roughness is obtained at experiment No.2 and the pulse on time of 4 micro seconds.

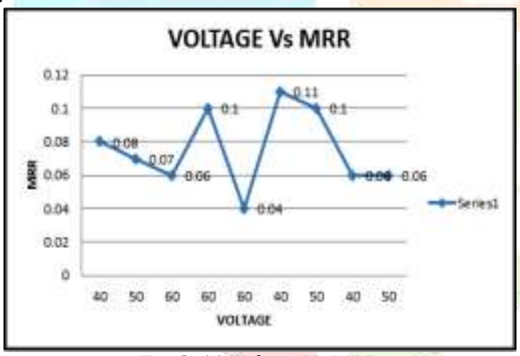


Fig. 3. (a) Voltage Vs MRR

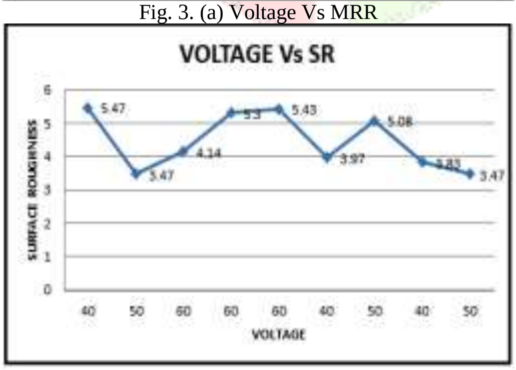


Fig. 3. (b) Voltage Vs SR

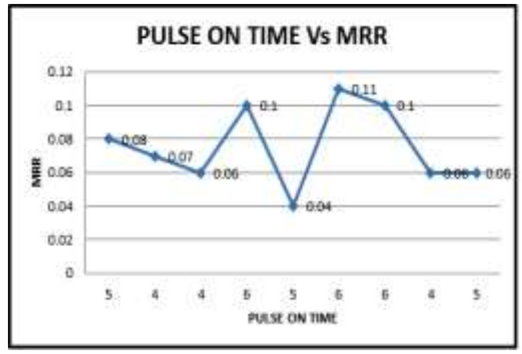
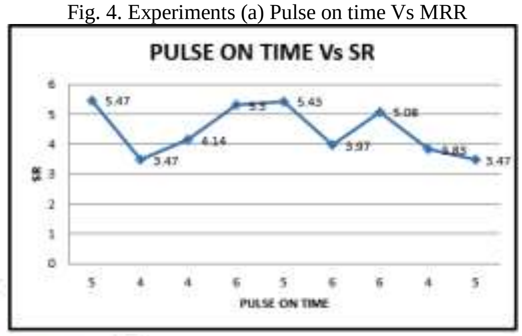


Fig. 4. Experiments (a) Pulse on time Vs MRR



(b) Pulse on time Vs SR

The graphs constructed with respect to Pulse off time Vs MRR and Pulse off time Vs SR are illustrated in the figure 5. It indicates that the maximum material removal rate is obtained at experiment No.6 and the pulse off time of 4.5 micro seconds. Also the minimum surface roughness is obtained at experiment No.9 pulse off time of 4.5 micro seconds.

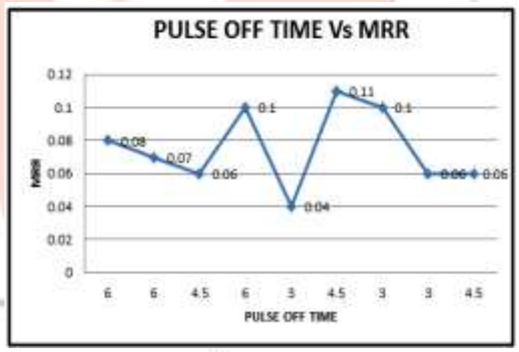
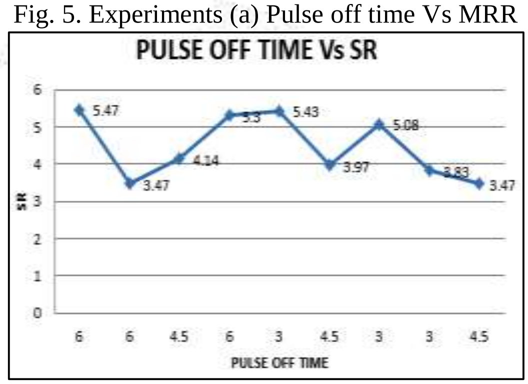


Fig. 5. Experiments (a) Pulse off time Vs MRR



(b) Pulse off time Vs SR

5. CONCLUSIONS

The machinability studies of Wire EDM on Al6061/ 20%SiC MMC were conducted and based on the experimental analysis the following conclusions were drawn.

- The maximum material removal rate is obtained when the input current was increased to 3 amps with 40 Volts and Pulse on & off time of 6 & 8 microseconds respectively.

- The minimum surface roughness is observed at maximum input voltage and lower input current condition. And its corresponding parameters of 1 amps of current with 50 Volts and Pulse on & off time of 5 & 8 microseconds respectively

- It is noted that maximum material removal rate is achieved in increment of more current and minimum surface roughness is achieved from minimum current value.

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