Experimental Investigation of Machining Performances of Al6061-SiC Metal Matrix Composite through Wire EDM

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Abstract - *The Al6061 alloy reinforced with SiC particle is casted by stir casting technique. SiC with 37µ size is used by varying the percentage of SiC from 0%, 5% and 10% by weight and specimens are prepared.*

The experimental work consist of machining of Al6061/SiC composite using Wire Electro Discharge Machining . In this work the process parameters are Pulse-on time (TON), Pulse-off time (TOFF), Current (I) and Wire feed (Wf) are varied to find their effects on Surface roughness (Ra). The experiment will be carried out by varying the machining parameters. The Al6061 alloy reinforced with SiC particle size of 37 microns is casted by stir casting technique and varying the percentage of SiC 0%, 5% and 10% by weight and specimens are prepared. To conduct the experiment CNC wire EDM machine with brass wire is used. The experiments are proposed to carried out as per design of experiments (DOE) according to the selected L9 orthogonal array. The resultss are drawn from this analysis, which is presumed to be valid for manufacturing engineers to choose suitable WEDM process parameters for the MMCs of Al6061 reinforced with SiC machine at different proportions.

Key Words: ***MMC, Al6061/SiCp, WEDM. Response graph***

1. INTRODUCTION

In MMC's Base metals reinforced with other one or two metal to improve the properties of base metal. In aluminium base metal reinforced with SiC or Al2o3 improves Strength, Elastic modulus, wear resistance and stiffness. These MMC's have applications like aerospace, defence, automobiles, surgical components and sports equipments. Greater hardness of reinforced materials makes it difficult for traditional machining. Hence non- traditional machines like Abrasive jet machine, laser cutting and electrical discharge machining, etc. But there process have their own limitation to overcome these limitation, Wire-Electro Discharge Machining has greater application.

Wire electrical discharge machining is a non-traditional thermo-electric machining process capable of accurately machining parts with varying hardness or complex profiles. WEDM uses electricity to cut any conductive material precisely and accurately with a thin, electrically charged Molybdenum, copper or brass wire as an electrode.

In our investigation, since Al6061 has greater applications in aeronautics, automobile industries and civil structures because of good versatility. Good corrosion resistance and mechanical properties with appropriate thermal treatment.

2. LITERATURE REVIEW

Prashantha et al. [2016] have discussed about the SiC particle reinforced Al6061 alloy casting by the stir casting technique. Wire Electro Discharge Machining is used to improve the process characterization of the Al6061/SiC composite. The parameters selected in this method are pulse-off time (TOFF), pulse-on time (TON), bed speed (BS) and current (I) to determine their effects on the Material Removal Rate (MRR). The experiments are proposed to be carried out in accordance with the chosen L9 orthogonal array as per the design of experiments (DOE). Results from this study are presumed to be applicable to the selection of suitable WEDM process parameters for Al6061 machine MMCs reinforced with SiC in different proportions by manufacturing engineers.

Abhay and Nilesh [2018] have addressed that the WEDM process now has wide-ranging applications in the aerospace, automotive, aircraft, rail, defense, micro-system industries, farm machinery, etc. Material matrix composites (MMCs) are advanced materials with properties such as light weight, high specific strength, strong wear resistance, low density, low coefficient of thermal expansion. These materials can be processed using non-conventional methods such as laser cutting and water jet, but only linear cutting is possible. Wire Electrical machining discharge (WEDM) shows increased ability to cut high precision complex shapes for MMCs. Conventional MMC machining causes serious tool damage due to higher longevity and abrasive surface particles. Since its inception, numerous studies and work have taken place in modeling of WEDM. Many researchers have worked extensively on process modeling, process parameters, electrode / tool work piece material, dielectric medium, etc... WEDM is considered as a primary objective for process modeling.

Gurupavan et al. [2016] have addressed that, the surface roughness, accuracy, volumetric material removal rate and electrode wear were investigated on the base of the machining parameters such as pulse-on, pulse-off, current and bed speed. The experimental work includes the development of composite materials for aluminium silicone nitride with Wire EDM (WEDM). Experimental analysis will be performed to study variations in performance parameters such as surface roughness, accuracy, wear of electrodes and removal of volumetric material under different machining conditions. Use sophisticated diagnostic tools such as the Artificial Neural Network (ANN) to measure surface roughness, volumetric MRR, accuracy and electrode wear

Palanisamy et al. [2019] have discussed that, the use of Electrical Discharge Machining (EDM) to overcome challenges in the manufacture by traditional machining of geometrically complex forms or machining of hard materials in this process, the inputs such as the discharge current (A), Pulse On-Time (B) Pulse Off Time (C) Current (D) Bed Speed , reduced surface roughness and a tool-wear rate (TWR) for LM6-Alumina Stir casting metal matrix composites (MMC) are optimized for achieving optimum metal removal rate (MRR) . Grey relation analysis is used to develop and optimize the above mentioned multiple performance features. This study shows that the discharge current is the most important parameter affecting the surface finish and the metal removal rate.

Vijay et al. [2019] listed Wire electric discharge process [WEDM] for the manufacturing of conductive, hardened materials such as composites of metal matrix, ceramic and super alloys with huge applications in the spacecrafts, defence, transport vehicles, micro, farm machinery, etc. Products based on aluminium - ceramic particulate reinforced metal products are a key element in the manufacture of composites that boost mechanical and thermal properties. Such Al-MMCs are suitable for a variety of engineering applications, because of their higher strength and rigidity. The current paper explores the optimisation of WEDM machining parameters by applying different techniques.

Ashish et al. [2014] have discussed an experimental study on Al2024 composite reinforced with SiC to investigate the effects of Wire Electric Discharge Machining (WEDM) on three rates of each parameter, such as current, time pulse, and percentage reinforcement on surface finish and Material Removal Rate (MRR). Response surface methodology (RSM) technique was applied to optimize the parameters of machining for minimum surface roughness and maximum MRR. The percentages of SiC length for strengthening. With peak current and pulse duration increased, the SR increased.

Samy et al. [2004] have developed a mathematical modeling of Al-SiC composites for the WEDM. They optimized WEDM characteristics such as MRR, cutting speed, and developed the SR. Average machining voltage, pulse frequency, work piece height, kerf size and SiC percentage volume fraction present in the Aluminum Matrix are considered as process parameters.

3. Wire Electrical Discharge Machining (WEDM)

Wire EDM is a method to cut conductive materials with a thin wire electrode of diameter ranging from 0.004''- 0.012'' which follows a programmed path. There is no physical contact between the part and wire electrode being machined. The wire is surrounded by de-ionized water. The wire is changed to a voltage reaches the correct value a spark jumps the gap and generate a heat around 15,000-21,000 Fahrenheit, which melts and erodes small tiny bit of material from the work piece. De-ionized water cools and flushes this melted small particles of size about ±0.0001" from the gap. No burs are generated, since there are no cutting forces. A schematic diagram of the basic principle of WEDM and cutting process are shown FIG. 1 and FIG. 2.

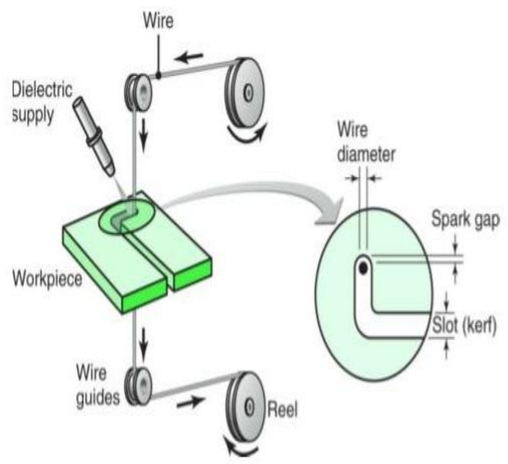

Fig.-1: Schematic Diagram of the Basic Principle of WEDM

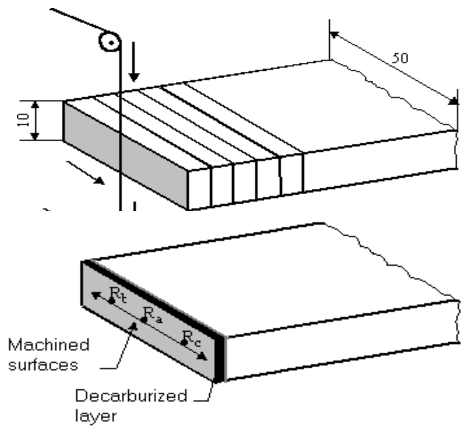

Fig.-2: Schematic diagram of the cutting process and Examination surfaces

4. MATERIALS AND EXPERIMENTAL METHOD

In this research a composites of base metal Al6061 is reinforced with silicon carbide with minimum of 0% to maximum of 10% prepared by stir casting technique.

The test pieces are square composites bar of material, 100mm x 100mm x 50mm, that are milled from the casted material. The prepared specimens are composite material Al6061 reinforced with 0 % SiC, 5% SiC and 10% SiC respectively. These specimens are mounted on SODICK A350 CNC WED Machine and specimens are cut in to

10mmx10mmx50mm size using machining tool. The fixtures used for cutting the specimens.

The experimental set-up for the data collection is illustrated in the Figure 3. The WEDM process generally consists of several phases, a rough cut phase, a rough cut with finishing stage, and a finishing stage. But in this WEDM machine we used only one pass.

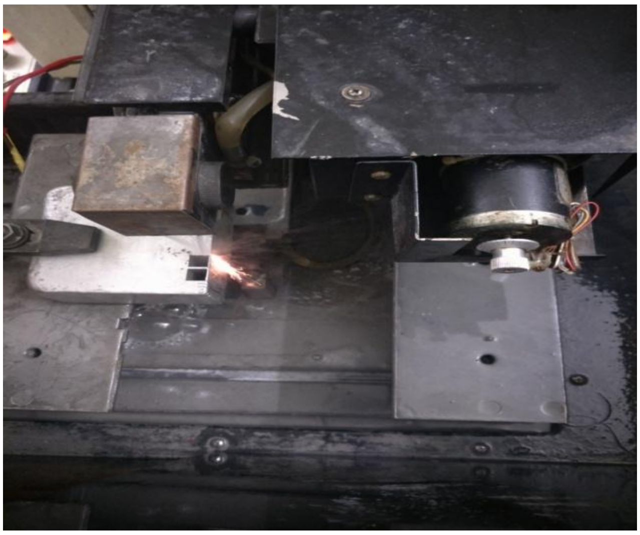

Fig.-3: Experimental Setup

And the properties of the Al6061 alloy and Silicon carbide are shown in table 1 and table 2.

Table -1: Properties of Aluminium 6061 Alloy

Density	2.7 g/cc
Melting Point	582-6520C
Ultimate tensile Strength	310 MPa
Young's Modulus	75 GPa
Thermal Conductivity	167 W/m-K
Specific Heat	896 J/kg-k
Hardness	95 BHN

Table-2: Properties of Silicon Carbide (SiC)

Density	3.2 g/cc
Melting Point	2200oC
Ultimate tensile Strength	240 MPa
Young's Modulus	440 GPa
Thermal Conductivity	120 W/m-K
Specific Heat	750 J/kg.k
Hardness	90 BHN

For experimentation Taguchi method is applied. The WEDM process parameters and their levels, and L9 orthogonal array selected are shown in table 3 and table 4.

Table- 3: WEDM Process Parameters and their Level

Sl. No.	**Parameters**	**Levels**		
1	Pulse on time in µs (P_{on})	4	5	6
2	Pulse off time in µs (P_{off})	14	15	16
3	Current in Amps.	2	3	4
4	Wire Feed Rate in mm/sec	1	2	3

Table- 4: L9 Orthogonal Array

Run	**P_{on} in µs**	**P_{off} in µs**	**Current in Amps.**	**Wire Feed Rate in mm/sec**
1	4	14	2	1
2	4	15	3	2
3	4	16	4	3
4	5	14	4	2
5	5	15	2	3
6	5	16	3	1
7	6	14	3	3
8	6	15	4	1
9	6	16	2	2

5. RESULTS AND DISCUSSION

5.1 Effect of Pulse- on time on Ra value for various percentage of SiC:

In this situation, the surface roughness with respect to the pulse – on time in which different percentage of the SiC is shown in Fig. 4. From the fig. 3 It can be noticed that the surface roughness value increases with an increase in pulse on time, but the increase in the surface roughness at the margin is generally small, regardless of the percentage of SiC. This is due to the spark intensity in Wire Electro Discharge Machining process, which depends on the Pulse-on time. Wear rate of brass wire increases with increase in input energy, leading to wire breakage. It can also be review the Ra is decrease with increase in percentage of SiC.

5.2 Effect of Pulse-off time on Ra value for various percentage of SiC:

Differences in Surface roughness value with respect to Pulse-off time in which different percentage of SiC is as shown in the Fig. 5. It also reveals that the Surface roughness is decreasing as well as increase in pulse-off time. From the graph it appears that margin of decrease in Surface roughness value is greater with increase in pulse- of time from 14to 15 µs as compare to 15 to 16 µs pulse-off time. Surface Roughness improves with increase in pulse-off time. The surface roughness is high at low pulse-off time; this is due to the fact that with too short pulse-off time, there is not enough time to remove the melted small particles from the gap b/w of the wire electrode and the workpiece. It is noted that surface roughness first decreases with an increase in pulse-off time and then increases with an increase in pulse-off time. Ra value is decreases with increase in the percentage of SiC. It can also be recorded that, if the interval of time is too short, the ejected chips will not be flushed away with flow of dielectric fluid so as to fluid will not be deionised. Therefore, the minimum Pulse-off time has to be maintained for effective machining.

5.3 Effect of Current on Ra value for various percentage of SiC

The variation of Surface roughness value depends on current for various percentage of SiC is as shown in the Fig. 6. From Fig. 6. it is observed that the Surface roughness value is increasing with the increases in current but the margin of increases Ra is generally minute irrespective of the percentage of SiC. Increase in the value of Current will increase the pulse discharge energy which in turn can improve the cutting rate further. With increase in the value of current Ra increases. Current is found to be the major factor affecting the Surface Roughness. It can also be review the Ra is decrease with increase in percentage of SiC.

5.4 Effect of Wire feed rate on Ra value for various percentage of SiC:

The different Surface roughness value with respect to Wire feed rate of various percentage of SiC is as shown in the Fig. 7. From the Fig. 7. Shows that Surface roughness value is decreases with increase in Wire feed rate. From the graph a margin of decrease in surface roughness value is greater with increase in wire feed rate, because new wire comes in contact rapidly when wire feed rate increases. Low wire speed tends to breakage of the wire. But with the increase in wire feed, the consumption of the wire increases and the machining cost also increases. That is the Surface roughness value is generally inversely proportional for various percentage of SiC. The surface roughness value decreases with increase in Wire feed rate irrespective of percentage of SiC. It can also be review the Ra is decrease with increase in percentage of SiC.

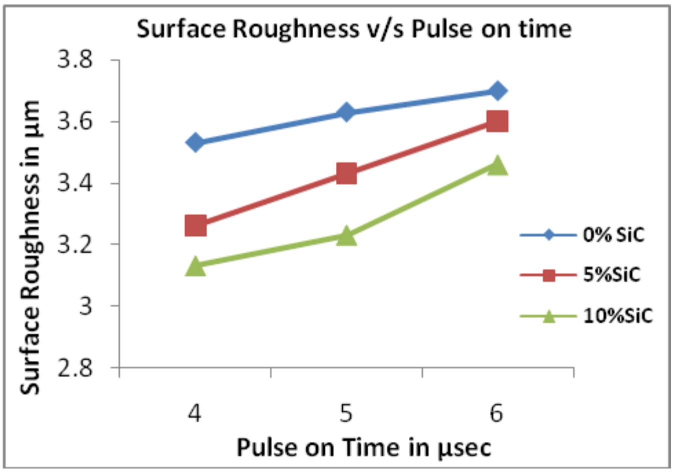

Fig.-4: Variation of Pulse on time on Surface Roughness

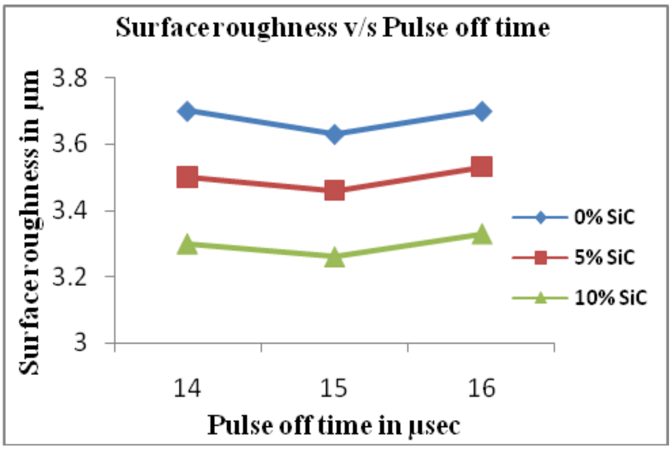

Fig.-5: Variation of Pulse off time on Surface Roughness

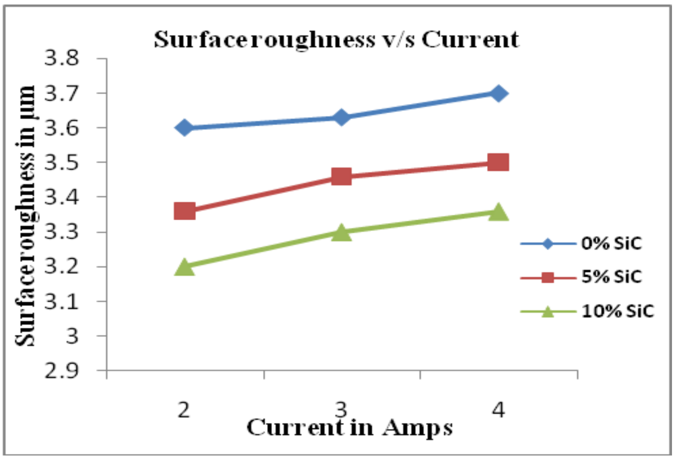

Fig.-6: Variation of current on Surface Roughness

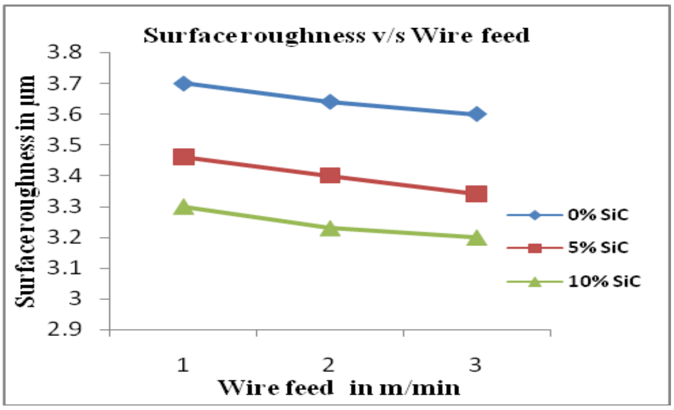

Fig.-7: Variation of Bed Speed on Material Removal Rate

From the above examination, it is recorded that the average Surface roughness for unreinforced Al6061 is obtained 3.64 μm observed from Fig. 4, 5, 6 & 7. In this case the Metal Matrix Composites Al6061 with 5% and 10% of SiC, the average Surface roughness are obtained is 3.43 and 3.27 μm respectively. This indicates that the increase in percentage volume of Silicon carbide particles in MMC's,decreases Surface roughness value. This accurse, due to the presence of harder Silicon carbide particles in MMC's. Reinforcement material enhances characteristics of aluminum consequently reduction in Surface roughness value.

6. CONCLUSION

The experimental studies were performed on a SODIC A350 four axis CNC WEDM for Al6061 alloy, Al6061 with 5% wt. SiC and Al6061 with 10% wt. SiC composite material using brass wire for various machining conditions. Taguchi's L9 orthogonal array was selected to conduct the experiments.

Based on experimental studies and based on obtained result the following conclusions are drawn.

- From the above analysis, Pulse on, pulse off, current and wire feed were considered as independent variables affecting the response variable to different extent.
- The average Surface roughness value for unreinforced Al6061 is 3.64 μm.
- Al6061 MMC's with 5% and 10% SiC, The average Surface roughness value is 3.43 and 3.27 μm, respectively.
- The Surface roughness value decreases with increase in various percentages of volume fractions of Silicon carbide particles in the Metal Matrix Composites.

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