Effect of Various Wire Electrode Materials on the Performance of Wire Electrical Discharge Machining of Al/SiC Composite Material

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Abstract - *In present investigation to analyzed the effects of various wire materials on the performance wire Electrical Discharge Machining of Al/Sic MMCs. Four control parameters such as pulse ON time, pulse OFF time, peck current, wire feed speed and two different wire electrodes namely Molybdenum wire electrode and Brass wire electrode have been considered. Taguchi L9 orthogonal array is selected to conduct the experimentation. The performance parameters such as Surface roughness, Electrode wear, Dimensional accuracy and Machining Time were measured while machining Al/Sic MMCs with different percentage of reinforcement that is 0%wt.,5%wt.,10%wt. of Sic in WEDM. The comparative study indicated that wire electrodes create the significant effects on the performance parameters. From the study it is observed that Brass wire gets smooth surface over other wire electrodes. Minimum Machining Time is obtained with Brass wire compare to Molybdenum wire. Better Dimensional accuracy was obtained during machining with Brass wire compare to Molybdenum wire. Additionally, it is observed that Electrode wear rate is seems to be more in case of Brass wire compare to Molybdenum wire.*

Key Words: **Wire electrical discharge machining Molybdenum wire, Brass wire, Surface roughness, Electrode wear.**

1. INTRODUCTION

The limitations of conventional machining process are the inspiration of research and development of new technologies in manufacturing process. Wire Electrical Discharge Machining (WEDM) is one of the greatest innovations affecting the tooling and machining industry. With the help of CNC wire electrical discharge machine (WEDM) it can be easily cut intricate shapes with best dimensional accuracy and surface requirements with economically. Wire electro discharge machining (WEDM) is the process of material removal of electrically conductive materials using the thermo-electric source of energy. It is one of the most extended non-conventional machining processes. Wire-cut EDM is typically used to machine mold tools such as punches, and dies from hard metals that are difficult to machine with conventional methods. In WEDM the conductive materials are cut with the help of series of electrical discharges that are produced between accurately positioned moving wire and work piece. In the wire EDM process the motion of the wire is very slow. It is fed from the programmed part and material is cut or removed from the work piece accordingly. Electrically conductive materials are cut by WEDM process by the electro thermal mechanisms. Material removal takes place by a series of discrete discharges between the wire electrode and the work piece, in the presence of a dielectric fluid Wire EDM uses a travelling wire electrode that passes through the workpiece, the wire is mounted preciosly by a computer numerical control system.like any other machine tool wire EDM removes material with electrically by meanse of sparks erosion. Therefore material that must be electrically conductive. Rapid DC electrically pulses are generated between the wire electrode and the workpiece. Between the wire and workpiece is a shield of deionized water called the dielectric. When the sufficient voltage is applied the fluid ionize, then a controlled spark preciosly erodes a small section of the workpiece, Causing it to melt and vaporize. These electrical pulses are reapeted thousands of time per seconds. The pressurised cooling fluid the dielectric cools the vaporized metal and forces the resolidified eroded paticles from the gap. The dielectric fluid goes through a filter which removes the suspended solids. Resin removes dissolved particles. To maintain the machine and part accuracy the dielectric fluid flows through a chiller to keep the liquid at constant temparature. AC or DC servo system maintain the gap from 0.51 to 0.176 mm between the electrode and workpiece. The servo mechanism prevents the wire electrode from shorting out against the workpiece and advances the machine as it cuts the desired shape. Because the wire never touches the workpiece, wire EDM is a stress-free cutting operation.

2. LITERATURE SURVEY

Rajeev Kumar et al [1]. presented experimental investigation to find the effect of different wire electrodes on performance characteristics. According to that cutting speed is maximum in case of steel wire electrode coated with cu and Zinc coated brass wire. Ruma sen et al. [2] investigated the influence of uncoated brass wire and silver coated brass wire on performance parameters of WEDM. From the investigation it is concluded that silver coated wire best suitable for machining Maraging steel compare to brass wire due to reduce surface roughness. Anshuman Kumar et al. [3] investigated the effects of tool electrode on machinability of

Inconel 718. From the investigation it is observed that Zink coated brass wire have better performance on surface roughness and corner error compare to uncoated brass wire. Vishya R surya et al. [4] focused on predicting and comparing the machining output of Al7075/Ti82 MMCs. From the experimentation and ANN predicted machining characteristics are n good agreement with experimental values. Jatinder Kumar et al. [5] conducted the study on the effects of wire electrodes in WEDM on machining of AISI D3 Die steel. According to the investigation improvements in surface finish with Brass wire compare to others wire were recorded.

3. EXPERIMENTAL SETUP

The experiments were performed on SODICK A350 four-axis CNC WEDM machine as shown in Figure 1. The purpose of this study is to study the effect of various wire electrode materials on machining of AL/SiC MMC's. The present study aluminum 6061 alloy was selected as matrix material due to its superior properties like corrosion resistance, fluidity, mechanical properties, electrical and thermal properties. The Silicon Carbide (Sic) particulate reinforcement material having 400 mesh size have been selected as reinforcement material respectively. The MMC's was prepared using a stir casting technique. For the experimentation three metal matrix components of different percentage of silicon carbide reinforcement that is 0%wt., 5%wt. 10%wt. of dimension 100mm x 100mm x 50mm was prepared respectively by using stir casting method.

The Taguchi L9 orthogonal array is used to design the experimentation. The design of experiments considered four control parameters with 3 levels each. Four control parameters were considered in order to examine the effects of various wire materials, such as pulse ON time (A), pulse OFF time (B), peak current (C) and wire feed (D). The other control parameters are kept constant. According to that nine experiments were conducted with different combination of input parameters. Totally eighteen components of dimension 10mm squares were cut in each Al/SiC MMC's (0%,5% &10%) nine components from molybdenum wire and nine components from brass wire electrode respectively. For experimentation SODICK A350 four axis CNC wire EDM machine is used. Two wire electrodes such as Molybdenum wire of diameter 0.18mm and Brass wire of diameter 0.25mm were selected for machining Al/Sic MMCs. The properties of wire electrodes are shown in Table1. The properties of Al6061 alloy and Sic reinforcement material as shown in table 2 and table 3. The surface roughness values of components machined with different wire electrodes was measured in terms of Ra value using surfcom flex tester. The electrode wear was measured using digital micrometer. The measured values are tabulated for further analysis.

Table -1: Properties of wire electrodes

Material	Hardness (VH)	Tensile strength N/mm^2	Conductivity (%IACS)
Molybdenum	160	324	34%
Brass	255	905	21%

Table -2: Properties of Al6061 alloy

Physical properties of Al6061 alloy	
Density	2.7 g/cc
Melting Point	582-652^{0}C
Ultimate tensile Strength	310 MPa
Young's Modulus	68.9 GPa
Thermal Conductivity	167 W/m-K
Specific Heat	0.896 J/g-^{0}C
Hardness	95 HRC

Table -3: Properties of Silicon carbide (Sic)

Physical properties of SiC	
Density	3.16 g/cc
Melting Point	2830^{0}C
Ultimate tensile Strength	525 MPa
Young's Modulus	440 GPa
Thermal Conductivity	200W/m-K
Specific Heat	0.67 J/g-^{0}C
Hardness	162 HRC
Poisson's ratio	0.17

Figure -1: SODICK A350 Four axis CNC WEDM

4. RESULT AND DISCUSSION

The surface roughness is an essential parameter during any machining operation because it decides the quality of the product and performance of the product. Higher the surface roughness value, lower the quality of the product. In a similar way electrode wear also one of the essential parameters that decides the cost of machining and quality of the machining. More wire wear rate increases the wire consumption causes more production cost, more wire breakage, and also quality of the component is lowered. Surface roughness and electrode wear are compared for two different wire electrodes performing on 0%wt., 5%wt., and 10%wt. SiC reinforced Al/SiC MMC's. The comparison statement of surface roughness and electrode wear of two different wires operated on 0%wt., 5%wt., and 10%wt. SiC reinforced Al/SiC MMC's. is shown in Table 4, Table 5 and Table 6.

Table -4: Measured output parameters for 0% wt. SiC MMCs

Surface roughness Ra in µm		Electrode wear in µm	
Molybdenum wire	**Brass wire**	**Molybdenum wire**	**Brass wire**
4.7	3.5	2	5
5.9	3.4	3	7
5.4	3.7	4	6
5.6	3.6	4	6
5	3.7	2	7
6	3.8	3	6
5.6	3.7	3	5
5.7	3.8	4	6
5.9	3.6	2	6

Table -5: Measured output parameters for 5% wt. SiC MMCs

Surface roughness Ra in µm		Electrode wear in µm	
Molybdenum wire	**Brass wire**	**Molybdenum wire**	**Brass wire**
4.6	3.2	3	6
4.4	3.3	4	8
4.6	3.3	4	7
5.2	3.4	3	7
4.8	3.4	5	8
5	3.5	4	7
4.8	3.6	5	7
4.6	3.7	4	8
5.2	3.5	5	7

Table -6: Measured output parameters for 10% wt. SiC MMCs

Surface roughness Ra in µm		Electrode wear in µm	
Molybdenum wire	**Brass wire**	**Molybdenum wire**	**Brass wire**
4.1	3.1	4	7
4	3.1	5	9
4.5	3.2	6	8
4.6	3.3	4	8
4.7	3.2	6	9
4.3	3.2	5	8
4.7	3.5	6	8
4.2	3.6	5	9
4.4	3.3	6	8

Figure-2: Comparison of Surface roughness using Molybdenum and Brass wire (0% of SiC)

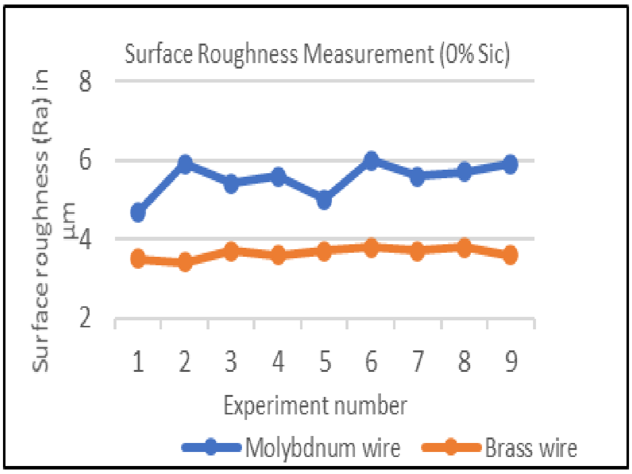

Figure 3: Comparison of Surface roughness using Molybdenum and Brass wire (5% of SiC)

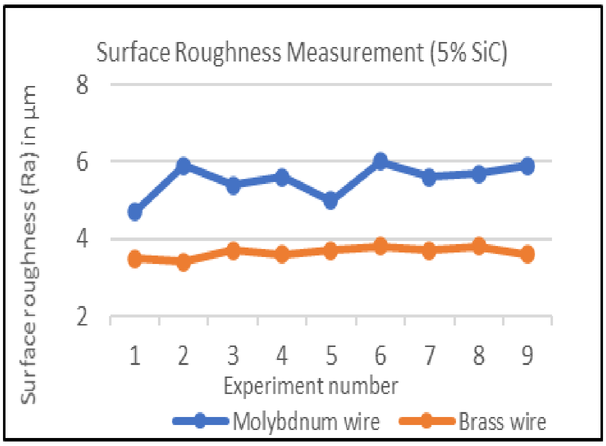

Figure 4: Comparison of Surface roughness using Molybdenum and Brass wire (10% of SiC)

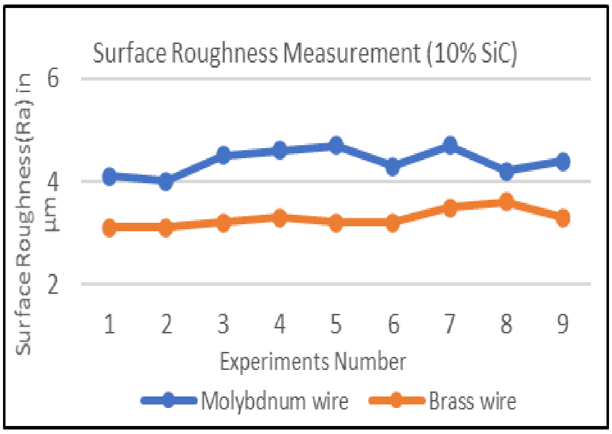

Figure 5: Comparison of Electrode wear using Molybdenum and Brass wire (0% of SiC)

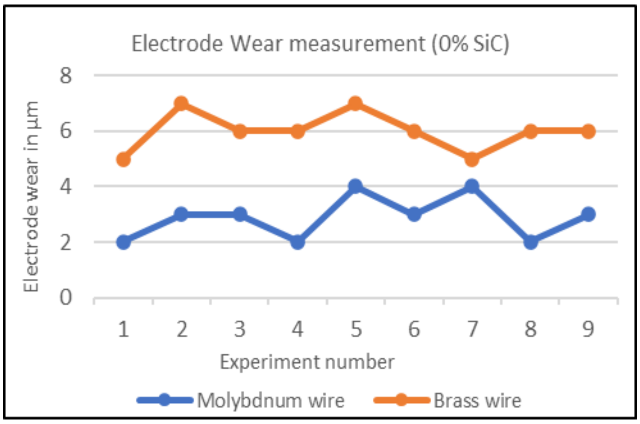

Figure 6: Comparison of Electrode wear using Molybdenum and Brass wire (5% of SiC)

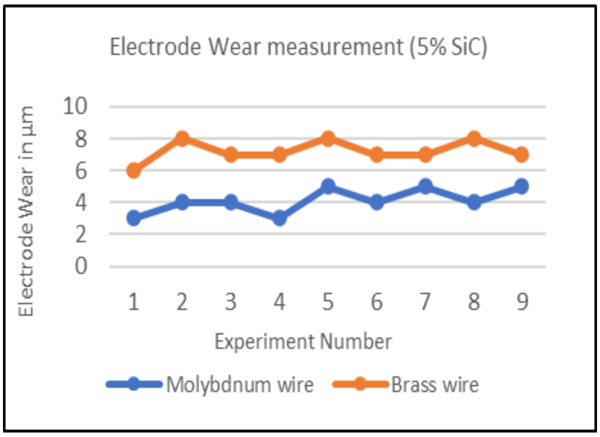

Figure 7: Comparison of Electrode wear using Molybdenum and Brass wire (10% of SiC)

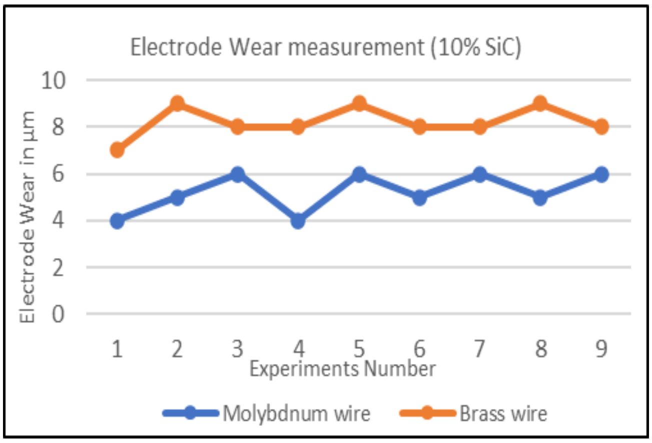

Figure 2, Figure 3 and Figure 4 shows the experimentally measured surface roughness values with respect to two different wire electrodes. For experimentation four input parameters with levels each having nine different combination et is used to machining Al/SiC MMCs. From the Figure 2 it is observed that smooth surface finish can be obtained with machining using Brass wire compare to Molybdenum wire for 0%wt. Sic reinforced MMCs. From Figure 3 it is observed that while adding 5%wt. of Sic reinforcement material in Al/SiC MMCs, the MMCs get hardened and strengthened. The surface quality also improved by increasing % of silicon carbide. By comparing two wire electrodes Brass wire gives good surface finish on Al/SiC MMCs. From Figure 4 it is observed that irrespective of hardened and strengthened of Al/SiC MMCs Brass wire gives better surface finish compare to Molybdenum wire.

Figure 5, Figure 6 and Figure 7 shows the comparison of experimentally measured electrode wear with respect to two different electrodes. The experiments were conducted on 0%wt., 5%wt. and 10%wt. silicon carbide reinforced Al/SiC MMCs in WEDM. From the graph it is observed that electrode wear rate is increased with increasing percentage of SiC in Al/SiC MMCs. It is observed that wear rate is more in case of Brass wire compare to Molybdenum wire due to hardness of the MMCs.

4. CONCLUSIONS

Wire electrical discharge machining [WEDM] has been found to be a promising machining technique for obtaining better surface quality on hard materials especially in AL/SiC MMCs.

The results of the present work identify

- Smooth surface finish is obtained using brass wire whereas, molybdenum wire produces rough surface.
- Brass wire electrode wear rate is more compare to Molybdenum wire electrode.
- Pulse ON, pulse OFF, current and wire feed were considered as independent variables affecting the response variables to different extent.
- Addition of SiC in base material the material gets hardened. During this study it is proven that it is possible to cut hard material in WEDM with less wire breakage.
- Machining cost of the component machined using brass wire electrode is less compare to component machined using molybdenum wire electrode.

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