An Experimental Study on Machining of Al-Sic (30%) Composite by EDM Process

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Abstract
To compete in market in present scenario there is a need of rapid product development causing the reduction in lead-time between the designs of the product to its arrival in the market. Engineering Composite Materials are gradually becoming very important material for their scope due to their high fatigue strength, thermal shock resistance, high strength to weight ratio etc. However machining of advance composites is very difficult by utilizing conventional machining method. Hence, it is essential for searching an advanced machining method by which machining of composite can be performed with ease and accuracy. To meet the requirement of micro machining of composite material, it is essential to develop a new machining method. For effective machining of AL6061/SiC (30%) composite, a electrochemical discharge machining (EDM) has been developed. The developed EDM has been utilized to machine holes on AL6061/SiC (30%). Material removal rate and tool wear rate were obtained experimentally for Brass and Copper tool Materials with different tool diameter and different levels of current.

Keywords
EDM, Brass, Copper, Composite, Aluminium.

I. Introduction

Fuelled by a growing need for high strength materials in technologically advanced industries and supported by the advances in the field of material science, there has been an increase in the availability and use of difficult-to-machine materials. Non-traditional machining processes are necessary for machining of such materials. EDM, ECM and ECDM are such process which is widely used to machine electrically conductive materials. Electrical Discharge Machining (EDM) is the process of machining electrically conductive materials by using precisely controlled sparks that occur between an electrode and a workpiece in the presence of a dielectric fluid. The electrode may be considered the cutting tool.

Figure 1.1 illustrates the basic components of the EDM process. Die-sinking (also known as ram) type EDM machines require the electrode to be machined in the exact opposite shape as the one in the workpiece. EDM differs from most chip making machining operations in that the electrode does not make physical contact with the workpiece for material removal. Since the electrode does not contact the workpiece, EDM has no tool force. The electrode must always be spaced away from the workpiece by the distance required for sparking, known as the sparking gap [1].

A. Working Principle of EDM

The basic fundamental of the process is that only one spark occurs at any instant. Sparking occurs in a frequency range from 2,000 to 500,000 sparks per second causing it to appear that many sparks are occurring simultaneously. In normal EDM, the sparks move from one point on the electrode to another as sparking takes place.

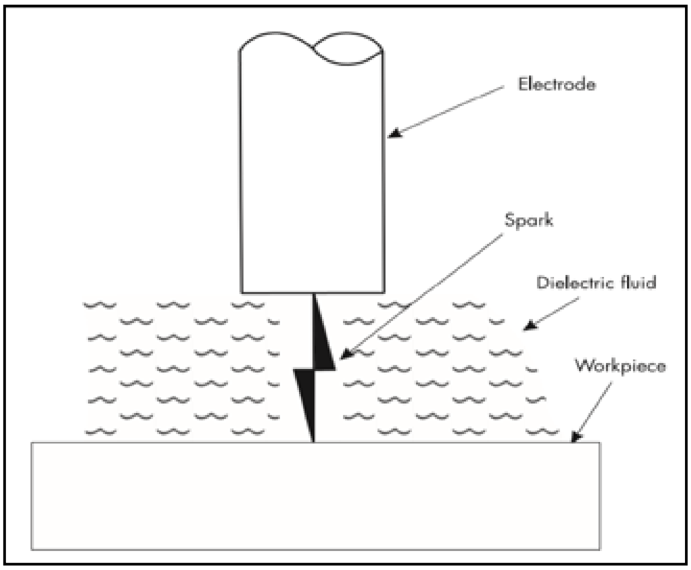

Fig. 1: Basic Components of EDM

The spark removes material from both the electrode and workpiece, which increases the distance between the electrode and the workpiece at that point. This causes the next spark to occur at the next-closest points between the electrode and workpiece. Fig. 2 illustrates how this works. EDM is a thermal process; material is removed by heat. Heat is introduced by the flow of electricity between the electrode and workpiece in the form of a spark. Material at the closest points between the electrode and workpiece, where the spark originates and terminates, are heated to the point where the material vaporizes. The area heated by each spark is very small so the dielectric fluid quickly cools the vaporized material and the electrode and workpiece surfaces.

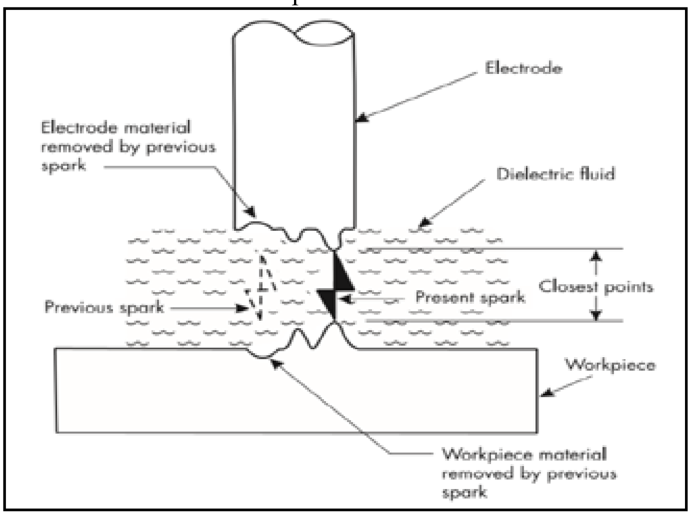

Fig. 2: How EDM Works

A dielectric material is required to maintain the sparking gap between the electrode and workpiece. This dielectric material is normally a fluid. Die-sinker type EDM machines usually use hydrocarbon oil, while wire-cut EDM machines normally use de ionized water. The main characteristic of dielectric fluid is that it is an electrical insulator until enough electrical voltage is applied to cause it to change into an electrical conductor. The dielectric fluids used for EDM machining are able to remain electrical insulators except at the closest points between the electrode and the workpiece. At these points, sparking voltage causes the dielectric fluid to change from an insulator to a conductor and the spark occurs. The time at which the fluid changes into an electrical conductor is known as the ionization point. When the spark is turned off, the dielectric fluid de ionizes and the fluid returns to being an electrical insulator. This change of the dielectric fluid from an insulator to a conductor, and then back to an insulator, happens for each spark [2].

B. Advantage of EDM

Some of the Advantages of the EDM process are as following:

1. Complex shapes can be generated that would otherwise be difficult to produce with conventional cutting tools.
2. Extremely hard material to very close tolerances can be machined.
3. There is no direct contact between tool and work piece. Therefore delicate sections and weak materials can be machined without any distortion.
4. A good surface finish can be obtained.
5. Very fine holes can be easily drilled.

C. Disadvantages of EDM

Some of the disadvantages are as following:

1. Slow rate of material removal.
2. Additional time and cost used for creating electrodes for ram/ sinker EDM.
3. Reproducing sharp corners on the work piece is difficult due to electrode wear.
4. Specific power consumption is very high.
5. Overcut is formed.
6. Electrically non-conductive materials can be machined only with specific set-up of the process.

D. Applications of EDM

1. EDM can be implied to machine any material that is hard, tough, brittle, provided it is electrically conductive.
2. It is used to make through cavities.
3. It can be used for making die for extrusion, wire drawing, moulding, casting, forging and forming etc.
4. It is used in automotive industry to produce precision injector nozzle holes.

II. Literature Review

EDM originated from the need to perform machining operations on difficult-to-machine metals. The process was developed almost simultaneously in the USSR and the USA at the beginning of World War II.

In 1941, the USSR was involved in World War II and critical materials needed to be conserved. Tungsten was widely used as electrical contact material for automotive-engine, distributor-breaker points. Dr. Boris Lazarenko and Dr. Natalya Lazarenko of All Union Electro Technical Institute investigated whether the life of the components could be extended by suppressing sparking between the breaker points. They observed that, while the oil did not eliminate the sparking, it did create more uniform and predictable sparking and pitting, as compared to operating the breaker points in air [3].

Ali et al (2013) investigated the Effect of EDM Die-sinking Parameters on Material Removal Rate of Beryllium Copper Using Full Factorial Method and found that the machine voltage is the less significant factor, while peak current is the most significant factor. The higher value MRR can be obtained with combination of high level setting of peak current and pulse on time. The changes of peak current and pulse on time have contributed to a great influence of MRR. It can be concluded that a storage spark with higher energy is produced when increasing peak current, subsequently more heat is generated and substantial quantity of heat utilized in material removal [4].

Kumar N. et. al. (2012) did Comparative study for MRR on die-sinking EDM using electrode of Copper & Graphite. From the results it is found that graphite electrode is more favourable than the copper electrode for the machining of steel work piece for MRR and TWR. It is also found that overall cost for machining of hard material with the use of graphite electrode is comparatively less than cop- per electrode [5].

Singh J.,KumarV. (2012) Investigated Material Removal Mechanism and the Thermal Aspects in the Electrical Discharge Machining Process. The study defines operating principles as discharging sparks, vapour, and erosion processes using heat energy to process parts. The unconventional machining methods promise formidable tasks to be undertaken and set a new record in the manufacturing technology.The surface roughness increased as the 'peak current' and 'pulse on time' increased using the reverse polarity. The material removal rate was found to be more using straight polarity as compared to reverse polarity in the process. The scanning electron microscope study of powder mixed electric discharge machining process showed that the cavities produced were shallow and uniform [6].

Lee S.H., Li X.P. (2001) Studied of the effect of machining parameters on the machining characteristics in electrical discharge machining of tungsten carbide and concluded that For all electrode materials the material removal rate increases with increasing peak current. Graphite electrodes give the highest material removal rate followed by copper tungsten & then copper. For all the three electrode materials the machined w/p surface roughness increases with increasing peak current. With the electrode as cathode & the work piece as anode in EDM of tungsten carbide better machining performance can be obtained. The material removal rate generally decreases with the increase of open circuit voltage. The material removal rate decreases when the pulse interval is increased. There is a maximum material removal rate with pulse duration at all current settings [7].

SYED K.H. (2012) studied Performance of electrical discharge machining using aluminium powder suspended distilled water which resulted in high MRR, good surface finish, and minimum white layer thickness when compared with pure distilled water. The result obtained from the present investigation is extremely helpful for selecting the optimum machining conditions for W300 die-steel work material, which is extensively used in tool and die industries [8].

Chigal.G et.al. (2013) studied Machining of Al 6061/Sic (10%) Composite by Electro Chemical Discharge Machining (ECDM) Process and concluded that The DC voltage and electrolyte concentration is the most significant parameters on material removal rate wit53.88 % and 25.71 % contribution respectively. But electrolyte flow rate and bare tool tip length are less significant parameters as compared to above mentioned with 20.06% and 0.32% contribution respectively [9].

III. Experimental Setup

The setup comprises of the following parts as shown in Fig.3:

1. Power Control Unit
   - Transformers
   - Bridge Diode Circuit (Full Wave Rectifier)
   - Electromagnetic Relay
2. Tool
3. Work piece
4. Guideways
5. Dielectric Sump/ Reservoir
6. Work Table
7. Workpiece Holder

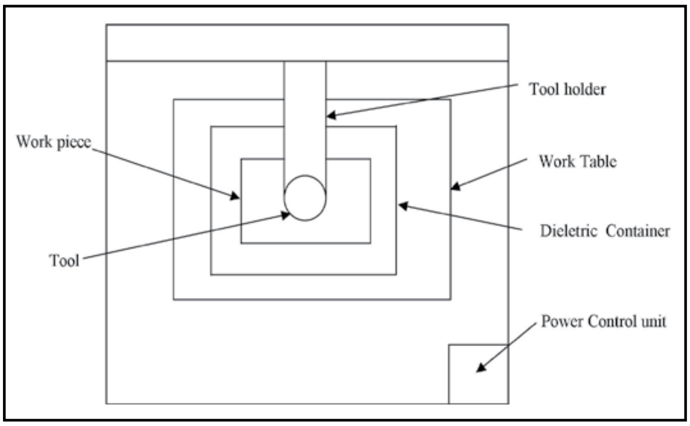

Fig. 3: Block Diagram of EDM

The fabricated unit consists of Electrical circuit, Guideways, Tool holder, Work piece holder and dielectric sump. The fabricated unit is a vertical type EDM, where in the guide ways are mounted on C-Angle on the work table. The dielectric sump is then mounted on guide ways and contains the dielectric fluid (Kerosene) and the work piece holder.

The tool will be placed vertically above the workpiece and it is held by an electromagnetic relay, which is adjusted to the rack and pinion arrangement which is held vertically by a horizontal beam. The horizontal beam is fixed to the vertical columns with the help of nuts to provide rigidity to the tool as shown in fig. 4.

Fig. 4: Experimental Setup for EDM Test Rig

IV. Results and Discussion

Twelve experiments have been carried out with variations of Tool Diameter (6mm and 8mm), Tool Materials (Brass and Copper) and Current (5 Amp, 3Amp and 1.5 Amp) by keeping the voltage constant at 24 V (DC) with kerosene oil as dielectric and results are presented in Table 1.

Table 1: Results for MRR and TWR

Sr. No.	Tool Material	Tool Diameter (mm)	Voltage (Volts)	Current (A)	MRR (mg/min)	TWR (mg/min)
1	Brass	8	24	5	2.22	1.43
2		6	24	5	2.19	1.37
3		8	24	3	1.96	1.28
4		6	24	3	1.92	1.24
5		8	24	1.5	1.64	1.06
6		6	24	1.5	1.60	0.97
7	Copper	8	24	5	2.38	1.57
8		6	24	5	2.31	1.54
9		8	24	3	2.11	1.36
10		6	24	3	2.06	1.34
11		8	24	1.5	1.83	1.13
12		6	24	1.5	1.79	1.11

Different graphs have been plotted to analyse the effect of various Electrochemical Discharge Machining (EDM) parameters on the machining characteristics.

A. Material Removal Rate (MRR)

Fig.5 and Fig. 6 shows the MRR for the EDM process by using Brass and copper tool respectively for different tool diameters. Both the figures shows that MRR for both tool materials increases with increase in tool diameter at all levels of current used in the process.

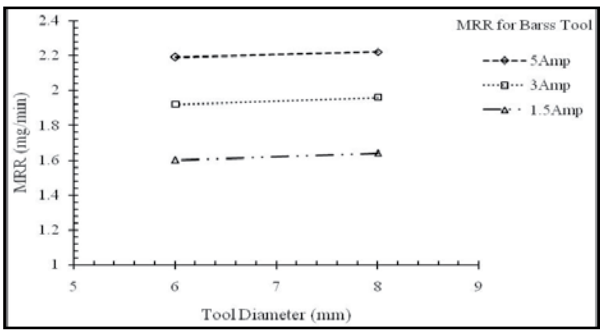

Fig. 5: MRR for Brass Tool

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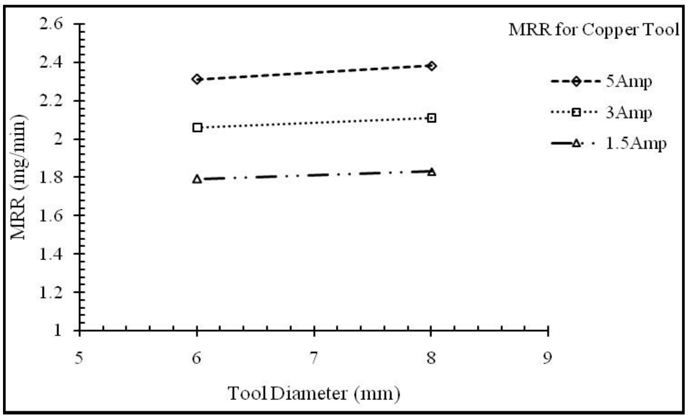

Fig. 6: MRR for Copper Tool

Fig. 7 and Fig. 8 shows the variation of MRR versus current and it is clear from these figures that MRR increases from with increase in the current for Brass as well as for Copper tool. It was also seen from these figures that the MRR is more for Copper tool than that of brass tool at all levels of current and for both the tool diameters. This increase in the MRR with rise in current is due to the reason that the spark becomes more intense at higher values of current and produces more heat which causes the more material removal as compared to the lower current. Fig. 8 shows that the increase in MRR for Copper with 8 mm tool diameter is from 1.83 mg/min to 2.38 mg/min for an increase in current from 1.5 amperes to 5 amperes.

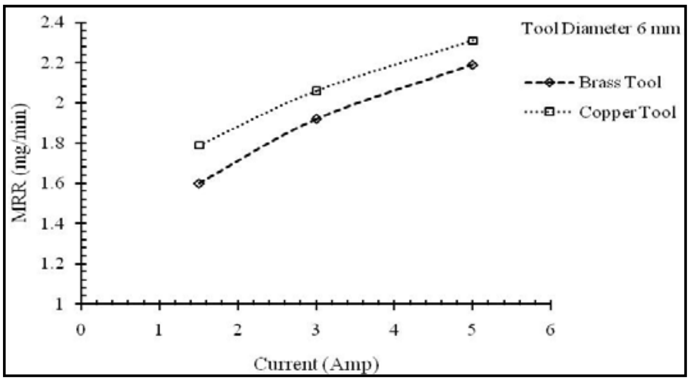

Fig. 7: MRR Versus Current for 6 mm Tool Diameter

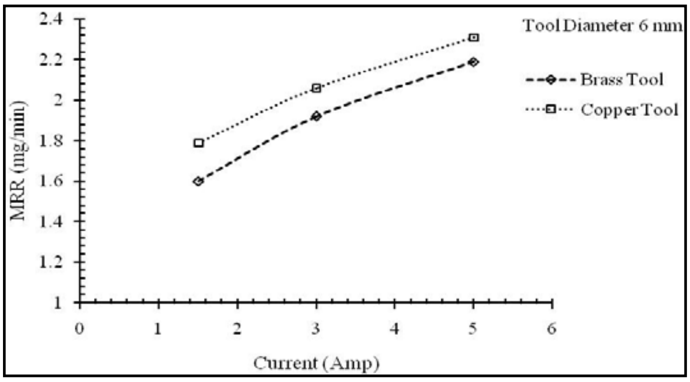

Fig. 8: MRR Versus Current for 8 mm Tool Diameter

B. Tool Wear Rate (TWR)

Fig. 9 and Fig. 10 show the variation of Tool Wear Rate (TWR) with tool diameter for Brass and Copper tool respectively. It is clear from the figure that TWR is more for the 8 mm tool diameter for both tool materials and selected current values.

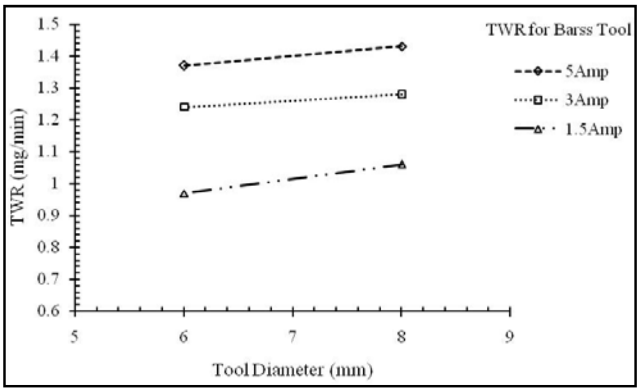

Fig. 9: TWR for Brass Tool

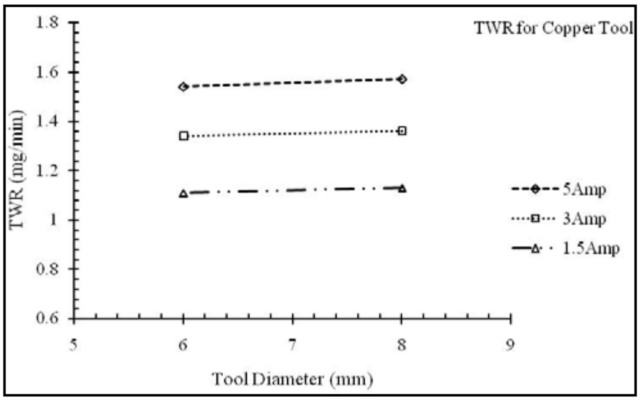

Fig. 10: TWR for Copper Tool

Fig. 11 and Fig. 12 are plotted for TWR versus current; these figures show that the increase in current value results the increase in TWR. The increase in TWR is directly proportional to the current. It is also clear from the figures that TWR is more for the Copper tool which is due to the higher thermal and electrical conductivity of the Copper as compared to brass. Fig. 12 shows that TWR ranges from 1.13 mg/min to 1.57 mg/min for range of current from 1.5 amperes to 5 amperes.

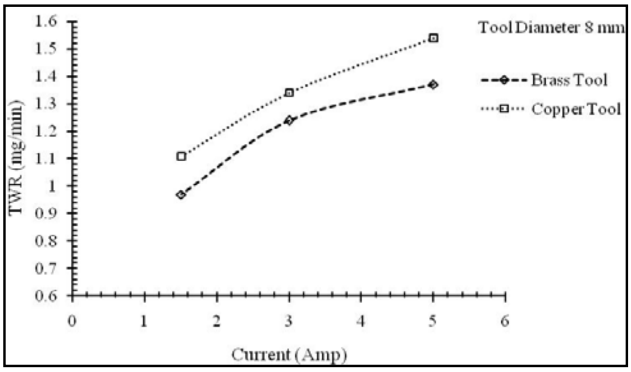

Fig. 11: TWR Versus Current for 6 mm Tool Diameter

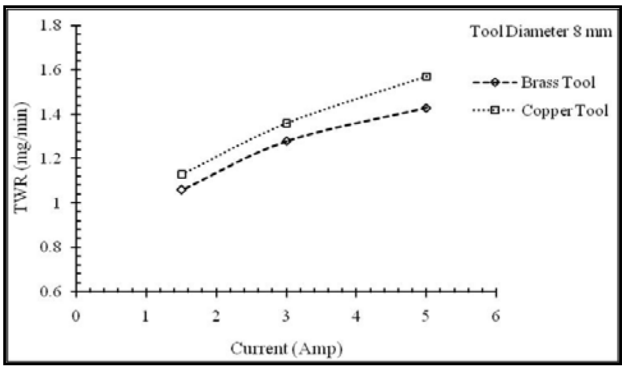

Fig. 12: TWR versus Current for 8 mm Tool Diameter

Fig. 13 represents the percentage increase in TWR for the change in value of current from 1.5 ampere to 3 ampere and from 3 amperes to 5 amperes for Brass and Copper tool materials. It is clear from the figure that percentage increase in TWR for 1.5-3 ampere is more than that for the 3-5 amperes. Also it shows that increase in TWR is more for the Copper tool material for current 1.5-3 ampere (15.44%) as compared to Brass (11.72%).

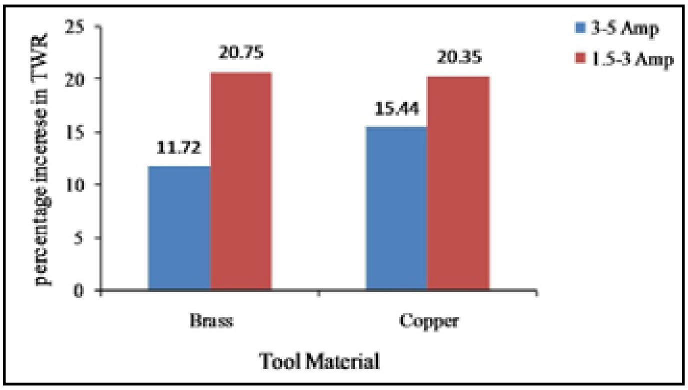

Fig. 13: Percentage Increase in TWR for Brass and Copper Tool Materials

V. Conclusion

Based on the experimental results it may be concluded that MRR and TWR are directly proportional to the current. It was seen that MRR for 8mm tool diameter at 5 amp current is 2.22mg/min for brass tool where as it is 2.38 mg/min for copper tool which is 0.16mg/min (7.21%) more than that of brass tool. Also the corresponding tool wear rate (TWR) was observed as 1.43mg/min for brass tool and for copper tool it is 1.57mg/min which indicates the TWR of copper tool is more by 9.79% as that of brass tool. So it may be concluded that Brass is more superior than copper for its life as tool material.

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