Comparative Analysis of Electric Discharge Sawing Machining with Conventional Electric Discharge Machining

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Abstract

Electric Discharge Sawing (EDS) Machining is similar to conventional Electric Discharge Machining (EDM) process, but extra reciprocating motion is given to the tool which enhances the flushing efficiency of the process which ultimately yields high MRR. Scotch yoke mechanism is used to generate reciprocating motion. There, still exist numerous difficulties in cutting advanced materials, super alloys and metal matrix composite materials. EDS is a competent sawing process for cutting difficult to cut materials. A modified setup has been designed and developed. The sawing process has been investigated with the developed setup. One-factor-at-time (OFAT) approach was used for experimentation. Experimental studies have been conducted on MMC with input parameters as current, pulse on time, pulse off time, gap voltage, lift, stroke length and rotational speed of disc, keeping other parameter constant. Material removal rate and tool wear rate of developed EDS process has been evaluated through standard test procedures. It has been found that the EDS process is quick as compared to the conventional cutting process. Now a days, there is massive demand of MMC shaft's in automobile industry. EDS may be an effective way to cut keyways and other operation in MMC shafts.

Keywords: EDS, OFAT, MRR and TWR

Introduction

Electric Discharge Machining (EDM) is an unconventional machining process and has its wide application in making moulds, dies, aerospace industries and in surgical equipments [1]. The process is based on removing material from a part by means of a series of repeated electrical discharges between tool called the electrode and the work piece in the presence of a dielectric fluid [2]. The material is removed with the erosive effect of the electrical discharges from tool and work piece [3]. EDM also has the advantage of being able to machine difficult-to-cut material like Titanium, Inconel etc. However, its low machining efficiency, higher Tool Wear Rate (TWR), poor surface finish and environmental pollution constrained its further applications [2].

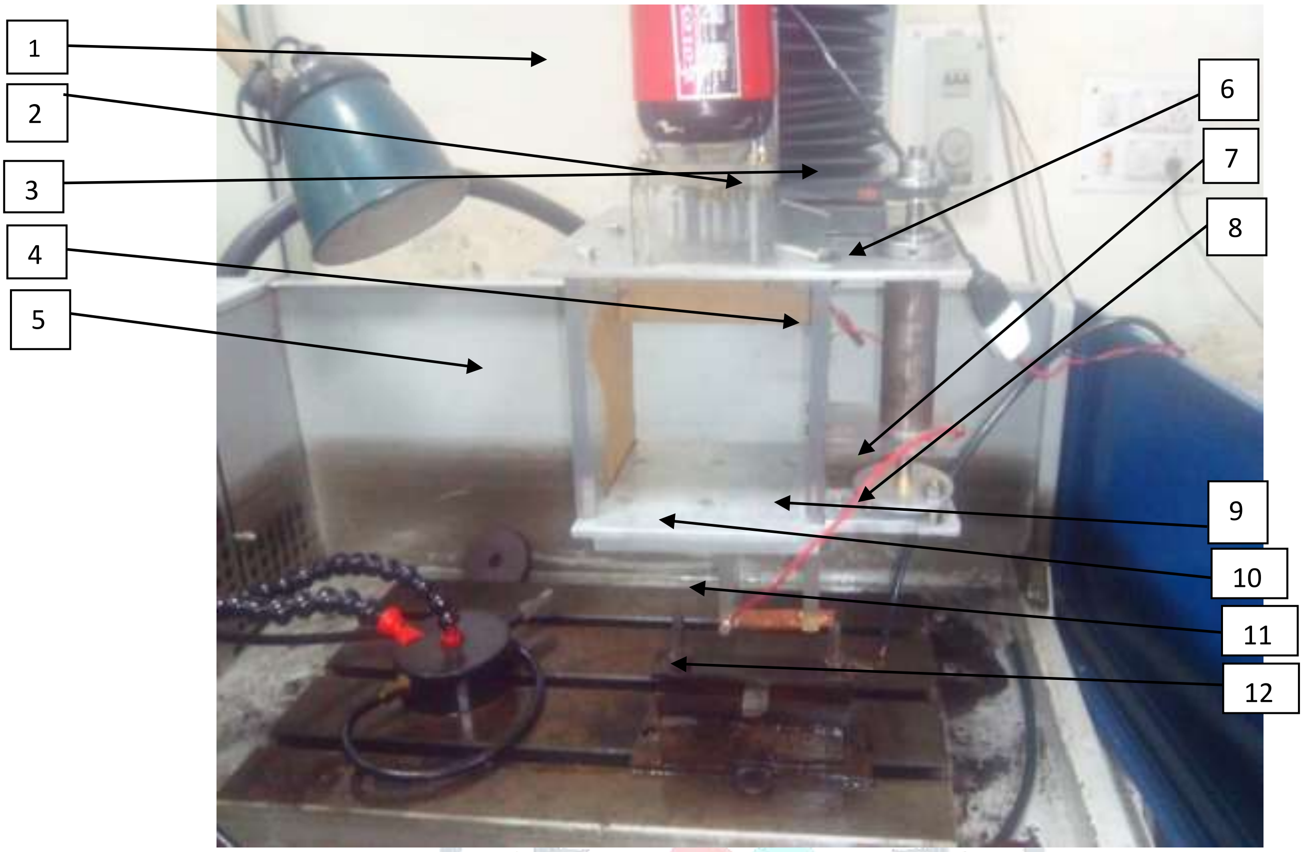
There still exist numerous difficulties in cutting advanced materials, super alloys and metal matrix composite materials. EDS is a competent sawing process for cutting difficult to cut materials. A modified setup has been designed and developed. The sawing process has been investigated with the developed setup.

In this paper EDS was studied through one-factor-at-time approach. Seven process parameters such as current, pulse on time, pulse off time, gap voltage, lift, stroke length and rotational speed of disc were selected for this purpose. The experiments were conducted on MMC (10% SiC reinforcement and matrix is Al 6063) as work material and pure copper as tool material. MRR and TWR were taken as results of experimentation and analyzed to determine the individually effects of process parameters.

Experimental setup

The experiments were conducted on the EMS 5030 die sinking EDM. The developed setup has been attached to an existing z-axis NC electrical discharge machining setup. The EDS process setup has been designed keeping in mind the crucial process mechanism as well as the logical requirement of various parts. The design of every part requires general selection criteria such as light weight, slight vibration should be there during the operation.

This type of operation is normally unstable, and the efficiency is very high. However, this process has a key problem caused by setup vibration at high rotational speed, which appreciably degrade the machining accuracy. The process performance in terms of maximization of material removal rate, minimization of the TWR (tool wear rate) has been experimentally investigated.



1. Eagle motor; 2. V- Belt; 3. V- Pulley; 4. Shaft Casing; 5. Vertical Supports; 6. Aluminium plate;

7. Disc; 8. Sliding yoke; 9. Sliding bar; 10. Guideways; 11. Copper Tool; 12. Workpiece;

Figure 1: Schematic of EDS (electrical discharge sawing) Setup

In the present work, copper tool of 0.7 mm thickness has been used to machine MMC (10% SiC reinforcement and matrix is Al 6063 workpiece).

Process Parameters

The experimentation was conducted with selected process parameters at different values using the one-factor-at-time (OFAT) approach taking MRR and TWR as quality characteristic. Process parameters (current, pulse on time, pulse off time, gap voltage, lift, stroke length and rotational speed of disc) were selected for OFAT by extensive evaluation of literature review. Table 1 shows variable process parameters.

Table 1 Variable process parameters

Current (A)	3,4.5,6,9
Pulse on time (µs)	90,120,150.200,300
Pulse off time (µs)	2,3,4,5,6
Gap voltage (V)	40,45,50,60
Lift	2,3,4,5,6
Stroke length (mm)	30,40,50
Disc (crank) rotational speed (RPM)	220,280,400,480
Other parameters (constant): Spark 4, polarity positive, flushing pressure 200 kgf/cm^2	

Effect of current on MRR and TWR

The Figure 2, shows the result obtained when current was varied with the values of pulse on time, pulse off time, gap voltage, lift, stroke length, and rotational speed of disc as 150 µs, 3 µs, 45 V, 3, 30 mm and 220 RPM respectively.

It was found from the results that increasing the value of current lowers the machining time and hence increases the material removal rate. It is due to the fact that as we increases the current we supply more electrical energy we get more work in terms of material removal rate in the similar manner tool wear rate also increases as we increase the value of current.

Further experimentations were carried out at 6 A current level. At this level of current, MRR and TWR were obtained satisfactory and surface quality was also better than 9 A current.

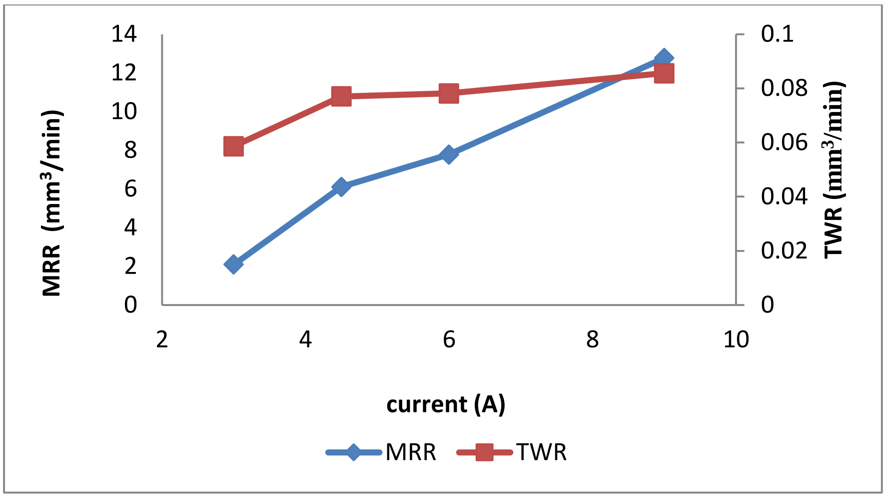


Figure 2: Effect of current on MRR and TWR

Effect of pulse on time on MRR and TWR

It is clearly visible from the Figure 3, that as we increases the pulse on time, firstly there is an increase in MRR, then it remains almost constant and further increase in pulse on time results in an increase in MRR further this can be justified with the fact that as pulse on time increases sparking time increase, longer pulse duration releases more energy at the workpiece leading to higher MRR. But it also leads to large craters on the workpiece surface and sometimes pits are also observed. A pit appears where the SiC particles have been removed in bulk. Further experimentations were carried out at 150 µs pulse on time. At this level of pulse on time, MRR and TWR were obtained satisfactory and surface quality was also better than 200 µs pulse on time.

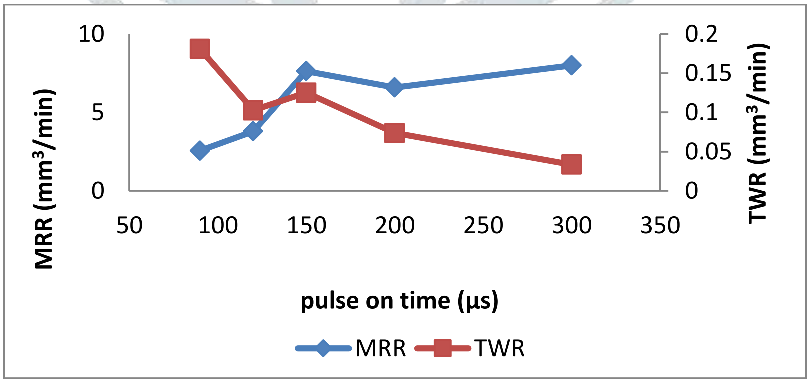


Figure 3: Effect of pulse on time on MRR and TWR

Effect of pulse off time on MRR and TWR

It is clear from the Figure 4, that as we increase pulse off time, firstly MRR increases, then after an optimum value it goes on decreasing. This is due to the fact that firstly as pulse off time is very less than proper flushing is not obtained so MRR is very less but as we increase the pulse off time we get proper flushing which enhances the MRR but after a particular value as pulse off, time further increase tool gets cool down and in the cycle unproductive time increases which results in a decrease in MRR.

Further experime0ntations were carried out at 4 µs pulse off level. At this level of pulse of time, MRR obtained is maximum and TWR were obtained satisfactory and surface quality was also better than 5 µs and 6 µs pulse of time.

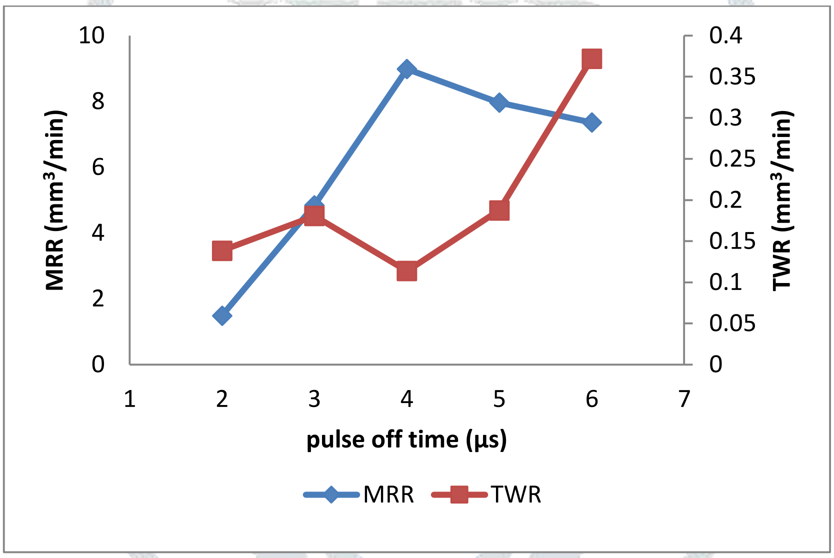


Figure 4: Effect of pulse off time on MRR and TWR

Effect of gap voltage on MRR and TWR

It is clear from the Figure 5, that as we increase the gap voltage, firstly MRR increase then it continuously decreases this is due to the fact that an inter electrode gap changes frequently so proper sparking is not obtained during the machining operation. Another reason of decreasing MRR with the increase in gap voltage is due to the uneven surface of tool which creates an obstacle to find a proper inter electrode gap. Another reason may be vibration present in the setup may result in reverse effects of gap voltage with MRR. Further experimentations were carried out at 50 V gap voltage level. At this level of gap voltage, MRR and TWR were obtained satisfactory and surface quality was also better than 60 V gap voltage level.

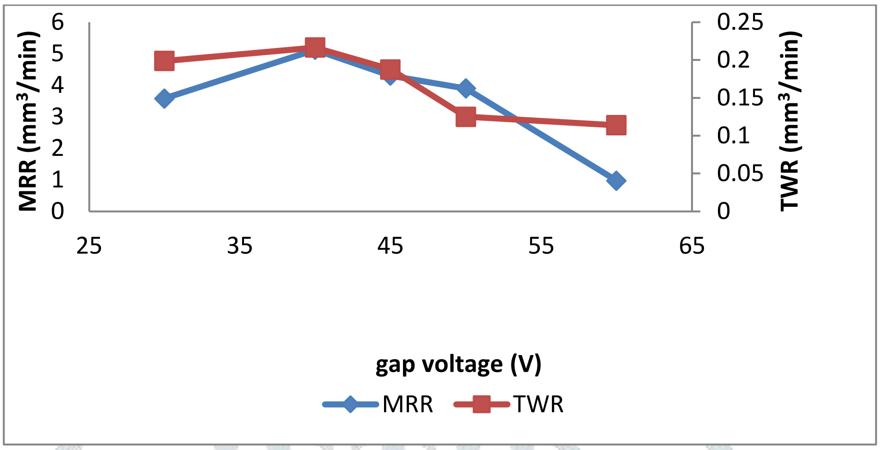


Figure 5: Effect of gap voltage on MRR and TWR

Effect of lift on MRR and TWR

It is clear from the Figure 6, that as we increase the lift, firstly MRR increases, but after a particular value it starts decreasing. This is due to the fact that firstly lift is very less so effective flushing is not obtained, but as lift increases proper gap between tool and workpiece is obtained which provides adequate space to wash away the debris. Therefore, MRR increases, but as we further increase the lift tool gets cooled down so it enhances the cutting time which ultimately results in decrease of MRR. Further, as lift increases, unproductive time in cycle increase, which results in a decrease of MRR. Similar results are obtained for TWR also. Further experimentations were carried out at 3 lift level. At this level of lift, MRR obtained is maximum and TWR were obtained satisfactory.

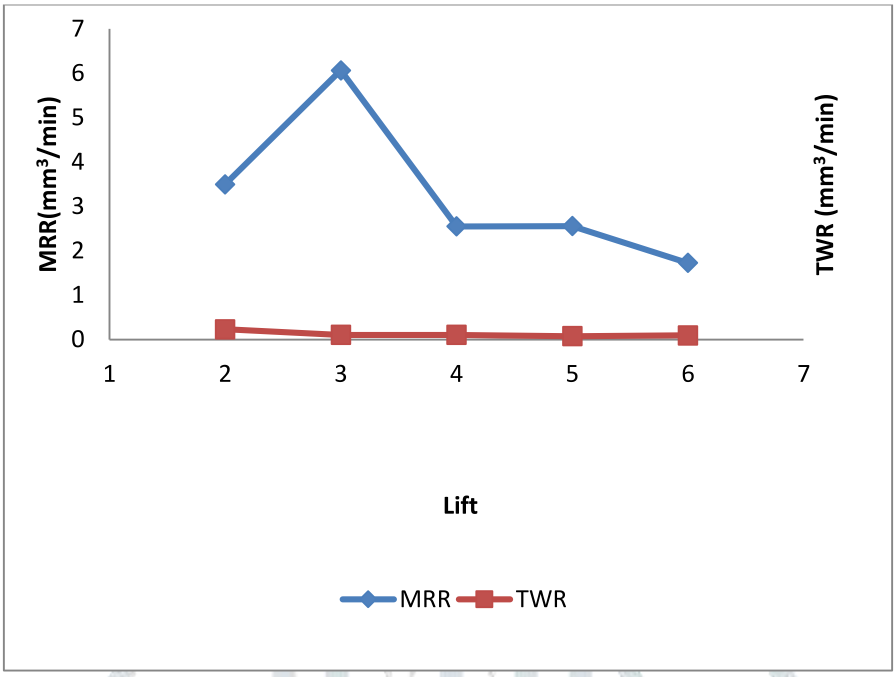


Figure 6: Effect of lift on MRR and TWR

Effect of stroke length on MRR and TWR

It is clear from the Figure, that as stroke length increases MRR decreases gradually. This is due to fact that as stroke length increase, the tool has to cover more distance as compared to the shorter stroke length so tool remains less time with the work piece which ultimately results in less MRR. Another reason may be waviness of the tool due to which it touches un-wanted locations which results in TWR at a faster rate and MRR decrease because cutting is not at the desired location. Further, there may be manufacturing defects (i.e. This may result in vibrations) in the setup causing inaccuracy in machining which ultimately results in low MRR and high TWR. Further experimentations were carried out at stroke length of 30 mm level. At this level of stroke length, MRR obtained is maximum and TWR were obtained satisfactory.

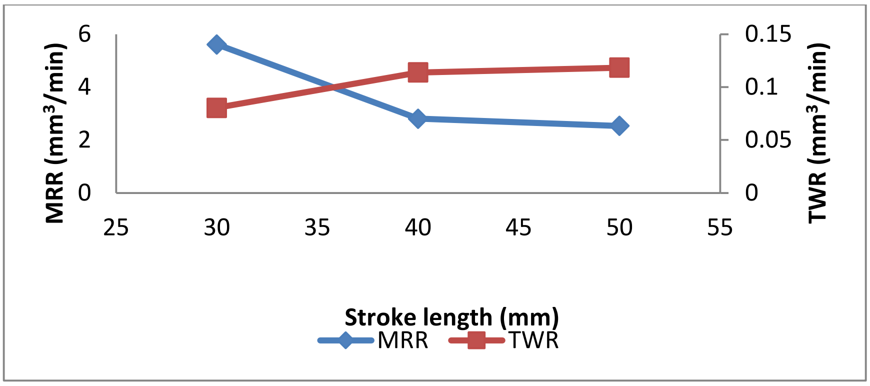


Figure 7: Effect of stroke length on MRR and TWR

Effect of rotational speed of disc on MRR and TWR:

It is clear from the Figure 8, that as rotational speed of disc increases firstly MRR and TWR increase and after a particular optimum value, MRR decreases. This is due to the fact that in our case MRR depends on flushing efficiency and proper sparking time. These two factors are responsible for MRR. As we increase rotational speed, it enhances the flushing which increases MRR but after a particular speed, MRR decreases due to improper sparking time which result in less sparking ultimately less MRR. Similar results are obtained for TWR also.

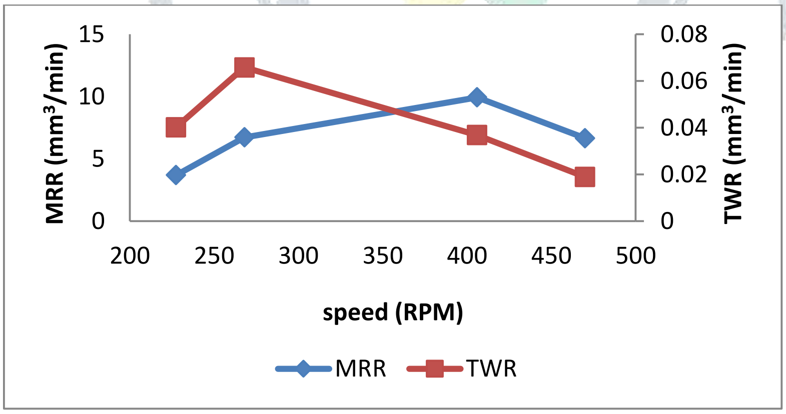


Figure 8: Effect of RPM on MRR and TWR

Comparison of Electric Discharge Sawing Machining with Conventional Electric Discharge Machining:

A comparison is done with conventional EDM process. It is found that due to extra reciprocating motion flushing efficiency increases which ultimately results in increase in MRR drastically. During comparison current (A), pulse on time (µs), pulse off time (µs), gap voltage (V), lift, stroke length (mm), rotational speed (RPM) are set 6, 150, 4, 50, 3,30, 400 respectively.

Percentage increase in MRR

$$\frac{MRR\ (\text{EDS}) - \text{MRR (conv.)}}{MRR\ (\text{EDS})} \times 100$$

$$\frac{\mathbf{7.930 - 6.978}}{\mathbf{7.930}} \times \mathbf{100} \cong \mathbf{12\%}$$

High MRR reduces cycle time which results in low product cost and ultimately gives an edge in this competitive world.

Result and Discussion

EDS as a non conventional machining method gives better results than conventional machining methods undoubtedly. Though the initial cost is higher, but this process is compensated by better results. After performing the experiments on MMC, it is found that the reciprocating motion of the tool provides additional flushing to the process. When a workpiece with a greater depth is machined from stationary tool, then the injection flushing becomes less effective to remove the debris from the machine zone. When reciprocating motion is given to the tool, the spark advances from one point to another which takes away the carbon particles with it and results in lower machining time and increases the material removal rate.

Figure 9: Machined Workpiece

Conclusion:

From the present experimental investigation, the following conclusions can be drawn;

a) EDS (electrical discharge sawing) set-up is feasible for machining of MMC’s.

b) The MRR achieved with the developed set-up is higher as compared to the conventional EDM process.

c) A higher setting of current leads to higher MRR.

d) The optimum value of pulse on time (150 µs) is obtained which leads to maximum MRR and lower TWR.

e) Similarly, the optimum value of pulse off time (4µs) is obtained which leads to maximum MRR and lower TWR.

f) Experiments also performed by varying the rotational speed and effects on MRR and TWR are obtained. An optimum value of rotational speed (400 RPM) is obtained which gives highest MRR.

g) Comparison with conventional EDM is also done and it is found that MRR drastically increases with the developed EDS setup.

The feasibility of the developed set-up can be investigated for machining of other hard to machine materials, such as titanium, Inconel, die steel, tool steel. These days there is huge demand of MMC shaft’s in automobile industry. EDS may be an effective way to cut keyways and other operation in MMC shafts.

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