

EXPERIMENTAL STUDIES ON EFFECT OF TOOL GEOMETRY OVER METAL REMOVAL RATE IN ECM PROCESS

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Abstract

Electrochemical Machining (ECM), over the past decades has become one of the important methods in metal removal processes. Electrochemical machining has established itself as one of the major alternatives to conventional methods for machining hard materials and complex contours without the residual stresses and tool wear. Studies on Metal removal rate (MRR) are of utmost importance in Electrochemical machining, since it is one of the determining factors in the process decisions. In this work, an experimental investigation has been made on various process parameters involved in the Metal Removal Rate using ECM on AISI 1035 steel with NaCl aqua solution for different tool geometries. The effect of tool geometry over metal removal rate has been studied in detail and results evolved. Theoretical metal removal rate has been calculated for different geometries and results are compared with the actual results.

Keywords: Electrochemical Machining (ECM), Process parameters, Tool geometry, Metal removal rate (MRR), NaCl aqua solution

1. INTRODUCTION

Electrochemical machining (ECM) has tremendous potential because of versatility of its applications, and it is expected that it will be a promising, successful, and commercially viable machining process in the modern manufacturing industries. ECM was developed initially to machine the hard alloys, although any metal can so be machined. The ECM process was first patented by Gusseff in 1929 (1). ECM is mainly utilized by the aircraft and aerospace industries for shaping, finishing, deburring, and milling operations of large parts. It is an anodic dissolution process. In this process, a low voltage (10-20 V) is applied across the inter electrode gap between a cathode tool and anode workpiece. The electrolyte flows at high speed through the gap. The anode workpiece dissolves according to Faraday's law. The dissolved material and other by-products such as hydrogen gas and heat are carried out by electrolyte flow. This process has more advantages than any other machining processes such as no tool wear, absence of stress/burr, high MRR, smooth surface finish. Irrespective of material hardness any complex shapes can be performed by this

process. ECM is an imaging process, where the cathode tool moves with feed rate towards the work piece and its negative mirror shape is reproduced in the work piece (2,3). This paper presents the effect of tool geometry on the metal removal rate (MRR). The experiments were conducted by using various tool geometries(4) and the results proved that the maximum MRR has been achieved on an inclined spiral geometry (electrolyte opening configuration) and circular geometry only. The effects of theoretical MRR compared with experimental MRR have been discussed.

2. WORKING PRINCIPLE OF ECM

ECM is a controlled anodic dissolution process which is shown in Fig 1. Here, work piece and tool are anode and cathode respectively, separated by an electrolyte. When an electric current of high density and low voltage is passed through the electrolyte, the anode work piece dissolves locally. So the final shape of the generated work piece is approximately a negative mirror image of the tool. The electrolyte, which is generally a concentrated salt solution flows through the inter electrode gap with high velocity to

intensify the mass/charge transfer through the sub layer near anode and to remove the sludge, heat and gas bubbles generated in the gap. Machining performance in ECM is governed by the anodic behavior of the work piece material in a given electrolyte (5).

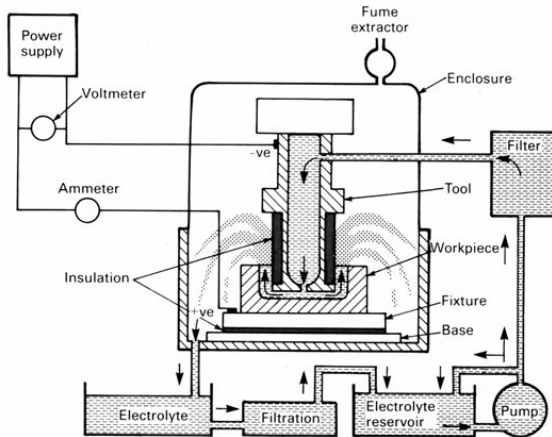
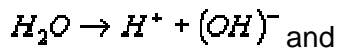


Fig. 1 Principle of ECM

When a potential difference is applied across the electrodes, several possible reactions can occur at the anode and cathode. The result of electrolytic dissociation



$NaCl \rightarrow Na^+ + Cl^-$ are negatively charged anions.

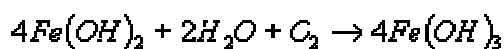
$(OH)^-$ and Cl^- which start moving towards anode, and positively charged cations: H^+ and Na^+ towards cathode.



At the cathode, the reaction is likely to generate hydrogen gas and the hydroxyl ions:



The outcome of these electrochemical reactions is that the iron ions combine with other ions to precipitate out as iron hydroxide $Fe(OH)_2$. The ferrous hydroxide may react further with water and oxygen to form ferric hydroxide:



The salt is not consumed in the electrochemical processes; therefore, for keeping constant concentration of electrolyte, it may be necessary to add more water. With this metal-electrolyte combination, electrolysis

has involved the dissolution of metal from the anode, and the generation of hydrogen at the cathode. No other actions take place at the electrodes (6).

3. EXPERIMENTAL WORK

The experimental setup includes an electrochemical machining unit, control panel and electrolyte tank. The power is supplied to the machining unit through a control panel. The control panel consists of LED's showing current, voltage, feed rate and a timer. The electrolyte used is 15g/l NaCl aqua solution. The electrolyte is filled in the electrolytic tank and is supplied to the machining unit by a pump. A rotameter is employed to measure the discharge rate of the electrolyte. Copper electrode has been used as an electrode and the pressurized electrolyte passes through the electrode. The setup is shown in Fig. 2.

The machining unit includes a spindle through which the electrode is inserted. The work piece is fixed in a vise and moved to the appropriate position using hand wheels. The maximum permissible current is set and the inter electrode gap is accurately set by touching the electrode and then feeding the electrode in reverse direction for the specified time. Then the machining is done for the set values. The performance of ECM is measured in terms of metal removal rate with current density, feed and electrolyte discharge for a constant inter electrode gap (0.1 mm) and voltage (12V).



Fig. 2. ECM set up

The selected different tool geometries and the experimental parameter details are shown in Fig. 3 and Table 1 respectively.

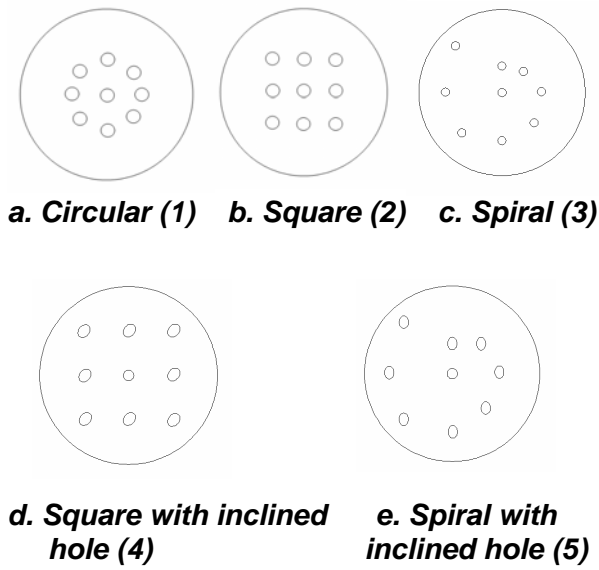


Fig. 3 Different tool geometries

Table 1

Experimental details	
Voltage	12 V
Current	0 - 250 A
Current density	0-53 A/cm ²
Inter electrode gap	0.1 mm
Feed range (mm/min)	0 -7.5
Power supply – DC	Continuous
Electrolyte flow	4.42-10.62 m/s
Electrolyte type	Salt solution
Electrolyte concentration	15 g/l
No. of geometries selected	5
Tool outer diameter	2.45 cm
No. of holes in the tool	9
Electrolyte temperature	20-30 °C
Work piece	AISI 1035
Time	3 minutes

4. RESULTS AND DISCUSSION

The current range for the ECM process is selected as 0-20 Amps DC (7). Fig 4 shows the effect of current on the metal removal rate for different tool geometries. The tools have been selected for experimentation according to the above mentioned order. The slope of theoretical MRR is constant according to Faraday’s law. But experimental MRR falls down after reaching its zenith. Initially set in the electrode gap may not be maintained throughout the process. There is every possibility that it reaches steady values with a

small band width. But experimental results slightly vary with theoretical results due to continuous variation of inter electrode gap, pressure drop of electrolyte or non homogeneity of material properties. It has also been observed that the higher MRR is achieved for circular (1) and spiral with inclined hole (5) geometries. So, the experimental results show that the tool geometry is one of the influencing factors for achieving the higher MRR.

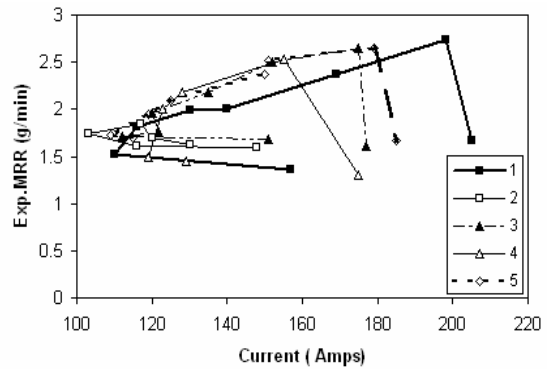


Fig. 4 Effect of current on experimental MRR for different tool geometry

Feed rates are selected from 0 to 0.75 mm/min for the processes of ECM. The experimental results revealed that as the feed rate increases, the MRR increases for certain time. Feed rate increases, the gap between the tool and work piece gets continuously reduced if the dissolution of work piece is not equal to the feed rate. The experimental results show that, at 0.64 mm/min is privileged for achieving higher MRR. The significant effect of feed rate on metal removal rate is shown in Fig 5.

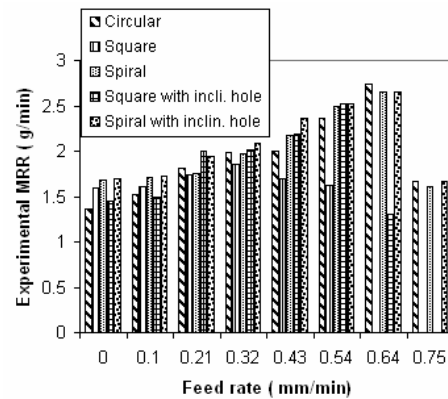


Fig. 5 Effect of feed rate on experimental MRR

Fig. 6 shows the effect of electrolyte flow rate on metal removal. The experimental results

exposed that the metal removal decreases as the electrolyte flow increases. Here also, circular geometry (1) and spiral with inclined hole geometry (5) give the better MRR than the other tools. The experiment results show that the higher range of MRR occurring only at the minimal quantity of electrolyte supply. (7.4 lpm)

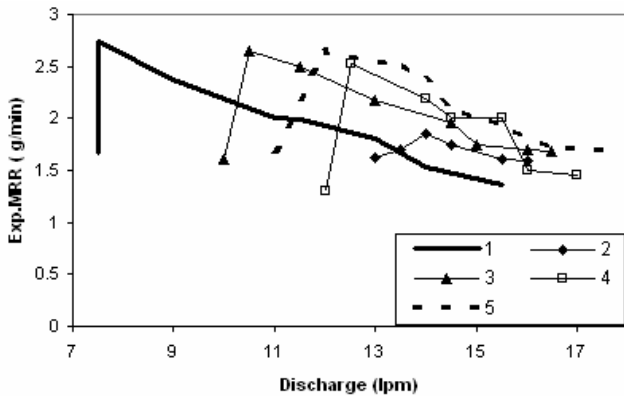


Fig. 6 Effect of electrolyte on experimental MRR

The experimental and theoretical MRR have been compared between circular (1) and spiral with inclined hole (5) geometries, Fig 7 shows that the bandwidth between the experimental and theoretical values gets reduced due to increase of feed rates. In spiral with inclined geometry has some advantages over the other patterns such like electrolyte distribution over the anode workpiece, percentage of area covered by the individual opening and turbulence.

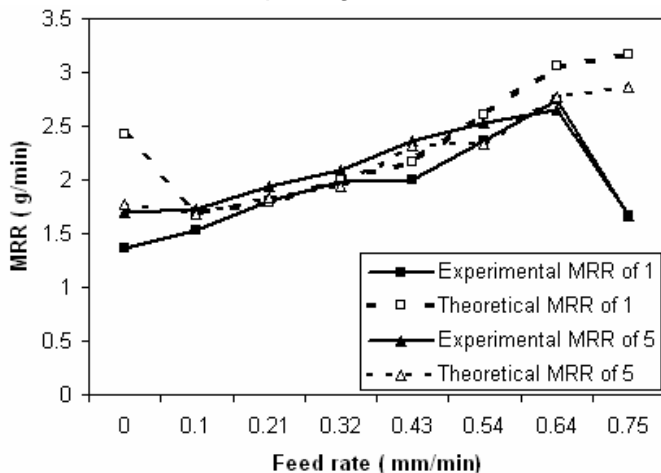


Fig. 7 Comparison between circular and spiral with inclined hole geometries

5. CONCLUSION

In this paper, the effects of tool geometry for various types on metal removal rate have been studied.

- The experimental results observed that how the influencing parameters such like current, federate and electrolyte discharge on various tool geometries affect MRR.
- In addition to this, tool geometry plays a vital role for obtaining better MRR.
- It is observed that the circular (1) and spiral with inclined hole (5) geometries yield better MRR than others.

6. ABOUT AUTHORS

Dr.R.Marappan has been working as a Professor and Head in the Department of Mechanical Engineering, Government College of Engineering, Salem since 2004 with two decades research experience and T.Sekar, Lecturer in Mechanical Engineering doing his doctoral research under the guidance of him.

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