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EFFECT OF VARIOUS PROCESS PARAMETERS ON MATERIAL REMOVAL RATE ON MILD STEEL IN ELECTROCHEMICAL MACHINING

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ABSTRACT
Electrochemical Machining (ECM) is a modern machining process based on the principle of electrolysis and hence it is generally termed as the reverse process of electroplating. Having very good characteristic's such as almost no tool wear, highly accurate machining, lesser thermal and mechanical stresses on workpiece makes this process beneficial than other modern machining processes. But still there are various process parameters that affects material removal rate. Keeping this in view, the present work has been undertaken to investigate the material removal rate by controlled anodic dissolution at atomic level of the electrically conductive work-piece with a hollow cylindrical copper electrode, stainless steel electrode and aluminium electrode. Mild Steel is taken as workpiece. Experiments were carried out to study the influence of machining parameters such as Electrolyte concentrations, current density and electrodes.

KEYWORDS: Electrochemical machining (ECM), Material removal rate, Electrolyte, Electrode, Inter electrode gap.

INTRODUCTION
Electrochemical machining (ECM) is a non-conventional machining process based on the principle of electrolysis and hence it is generally termed as the reverse process of electroplating or anodizing. Thus ECM can be thought of a controlled anodic dissolution at atomic level of the electrically conductive work-piece by a desired shaped tool due to flow of high current at relatively low potential difference through an electrolyte which is quite often water based neutral salt solution. ECM is one of advanced machining technologies and has been applied in highly specialized fields, such as aerospace, aeronautics, defense and medical industries [1]. Material removal rate (MRR) is the rate at which the work-piece material is dissolved per unit time. As the tool moves towards work, inter electrode gap decreases and current increases which cause more metal removal at a rate corresponding to the tool advance. MRR in case of electrochemical machining is based on the principle of electrolysis which is given by Michel Faraday. Faraday proposed two laws of electrolysis. According to the first law "The amount of chemical change produced by an electric current, that is, the amount of any material dissolved or deposited, is proportional to the quantity of electricity passed". According to the second law "The amounts of different substances dissolved or deposited by the same quantity of electricity are proportional to their chemical equivalent weights". Quantitatively, the Faraday's law (MRR in electrochemical machining) is given by the formula:

$$\mathrm{m} = ItA/\rho FZ$$

The machining is carrying out on mild steel. **S. S. Uttarwar et.al [2]** presented results of the Electrochemical Machining (ECM) process, which was used to machine the SS AISI 304. Specifically, the Material Removal Rate (MRR) and Surface Roughness (SR) as a function of ECM were determined. The experimental work was based on the Taguchi approach of experimentation and table L32 was used. The influence of independent parameters such as time of electrolysis, voltage, current, concentration of electrolyte, feed rate and pressure on output parameters material removal rate and SR was studied in this work. **Gangasagar et.al [3]** investigated the effect of different electrodes and process variables on the material removal rate and surface roughness of electrochemical machining (ECM) on EN8 alloy steel component. **S. K. Mukherjee et.al [4]** Studied about the material removal rate in electrochemical machining was analyzed in context of over voltage and conductivity of the electrolyte solution. **Dr. Saad Kariem Shather et.al [5]** focused on methods which are used to enhance metal removal rate (MRR) and surface finish during experimental investigations, were the work materials are two aluminum alloy (AL Zn Mg Cu 1.5-DIN 1725-1) and aluminum 1100 with using brass and steel ck35 tools, also NaCl solution as electrolyte was used. Experiments proved that increasing electrolyte flow rate from 6-14 l/min at electrolyte concentration 200g/l lead to increase metal removal rate reach to (63.07%) and enhancement of surface finish by reducing roughness from (5.07 - 3.25 µm) minimum and from (6.63 to 1.2 µm) maximum using work material from aluminum alloys to perform that . Also there are another factors influencing in metal removal rate and surface finish such as voltage and frequency when increasing them from (10-30) V lead to increase MRR about (29.45%) and frequency from (100-500) HZ improved MRR by (34.17%). **Andi Sudiarso et.al [6]** Studied on Material removal rate (MRR), which is an important aspect on an electrochemical machining. The results showed that the average MRR of brass was 2.96 x 10-4 g/s, stainless steel has MRR 2.54x 10-4 g/s, and MRR of aluminium was 7.9 x 10-5 g/s. For 6 mm of brass electrode, the MRR was 5.74 x 10-4 g/s and 2.53 x 10-4 g/s for 1 mm thickness of stainless steel and aluminium respectively. **Pradeep Kumar et.al [7]** investigated the improvement in the material removal rate of electrochemical machining. Experimental MRR had been calculated for different electrolytes condition on aluminum and stainless steel. The experimental results indicate that by using sea water as an electrolyte in electrochemical machining on aluminum alloy and steel alloy gives better MRR. **Kishor D. Patil et.al [8]** carried out an experiments using 24 factorial design and ANOVA for material removal rate of ECM on stainless steel. It had been observed that the material removal rate increases with increase in voltage, feed rate and electrolyte pressure. The electrolytic flow diameter, in studied range had a small effect on material removal rate (MRR) as compared to other three factors. **A.Mohanty et.al [9]** investigated the effect of process parameters such as electrolytic concentration, voltage and feed rate on performance characteristics such as material removal rate (MRR) and surface roughness (SR) when ECM of Inconel 825 by copper tool in an aqueous solution NaCl solution. It was observed that MRR increased with increase in voltage whereas SR decreased. Voltage was found to be significantly affecting the MRR and SR. An attempt has also been made to study the microstructure of machined surface at different conditions and to correlate it with multiple performance characteristics. **De Silva A.K.M et.al [10]** studied titled "Process monitoring of electrochemical micromachining" showed the importance of inter-electrode gap in ECM setup. **S. Kumara et.al [11]** discussed about the Material removal rate (MRR) of aluminum work piece has been obtained by electrochemical machining using NaCl electrolyte at different current densities. **R V Rao et.al [12]** discussed about the values of important process parameters of electrochemical machining processes such as the tool feed rate, electrolyte flow velocity, and applied voltage play a significant role in optimizing the measures of process performance.

EXPERIMENTAL STUDY

In this chapter we are going to discuss about the experimental work which is consisting about experimental set up, selection of various tool material, design of electrode, making of electrolytic solution and variation in current. By taking all this information in account we will calculate the material removal rate. Electrochemical machining ECM is the controlled removal of metal by anodic dissolution in an electrolytic cell in which the workpiece is the anode and the tool is cathode. The electrolyte is pumped through the gap between the tool and workpiece, while (D.C) direct current is passed through the cell, to dissolve metal from the workpiece. In this experiment following process parameter have taken to investigate the effect on material removal rate. The adapter provides D.C power supply with a peak to peak voltage of 12V. The electrolyte used was freshly prepared sodium chloride (NaCl) solution of 20%, 25% and 30% of NaCl in distilled water. The inner and outer diameter of hollow cylindrical electrode taken as 2 mm and 3mm respectively. Table 1 shows the various process parameters taken in this study.

Table 1. Process Parameters used for this experiment

Electrode	Stainless Steel, Copper, Aluminium
Workpiece	Mild Steel
Electrolyte	Sodium Chloride (NaCl) Solution
Frequency	50Hz
Voltage	12V
Current	5A, 10A
Electrolyte concentration	20%, 25%, 30%

RESULTS & DISCUSSION

In this experiment Material removal rate have found which is given by

MRR= (Initial Weight – Final Weight) / (Density X time)

Density of mild steel = 0.00785g/mm^3

Time = 5 Minute

MRR= (W_i – W_f) / (0.00785X 5) mm^3/min

3.1 Results at Current 5A and Nacl as Elecrolyte

In this study, experiments were conducted out on 9 samples of mild steel at current 5 amp taking NaCl as electrolyte with three different tool material (stainless steel, copper, aluminium) and at different electrolytic concentrations (20%, 25% & 30%). The results are summarized in table 2

Table 2: Results at Current 5A and Nacl as Elecrolyte

S. No.	Tool Material	Electrolyte Concentration (%)	MRR (mm^3/min)
1	Stainless Steel,	20	3.464
2		25	4.687
3		30	7.294
4	Copper	20	5.282
5		25	6.962
6		30	8.330
7	Aluminium	20	4.152
8		25	5.426
9		30	6.853

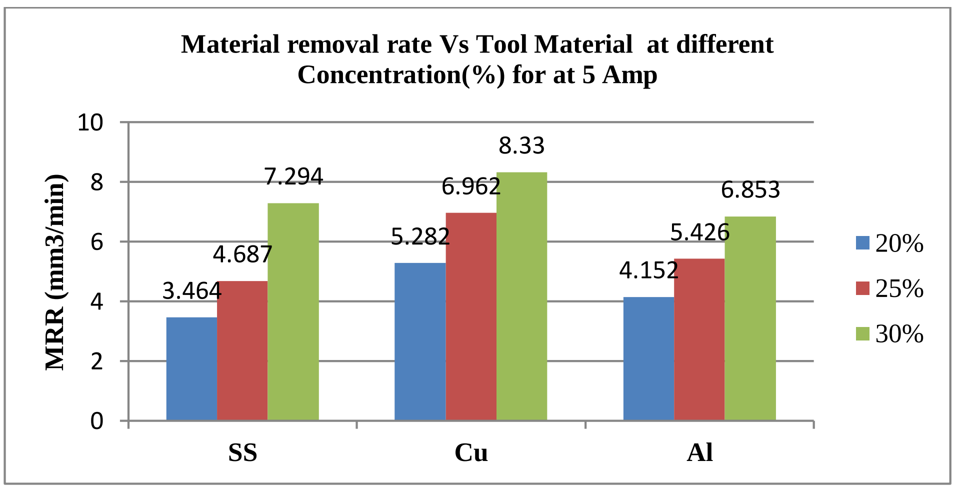

Fig. 1. Plot between Material removal rate Vs Tool Material at different Concentration (%) for at 5 Amp

From the table 3.1 it is observed that at 5 Amp current, the material removal rate increase as electrolytic concentration increases. By increasing the electrolyte concentration the electrical conductivity of the electrolyte increases and also that releases large number of ions in Inter electrode gap which results in higher machining current in Inter electrode gap and causes higher MRR. Also different electrode material affects the MRR. From table 3.1 it is showing that for copper electrode material the MRR is maximum as compared to Aluminium and stainless steel because of good electrical conductivity of copper.

3.2 Results at Current 10A and Nacl as Elecrolyte

In this study, experiments were conducted out on 9 samples of mild steel at current 10 amp taking NaCl as electrolyte with three different tool material (stainless steel, copper, aluminium) and at different electrolytic concentrations (20%, 25% & 30%). The results are summarized in table 3

Table 3: Results at Current 10A and Nacl as Elecrolyte

S. No.	Tool Material	Electrolyte Concentration (%)	MRR (mm^3/min)
1	Stainless Steel	20	5.197
2		25	8.991
3		30	12.152
4	Copper	20	10.396
5		25	12.967
6		30	14.929
7	Aluminium	20	7.719
8		25	10.623
9		30	12.228

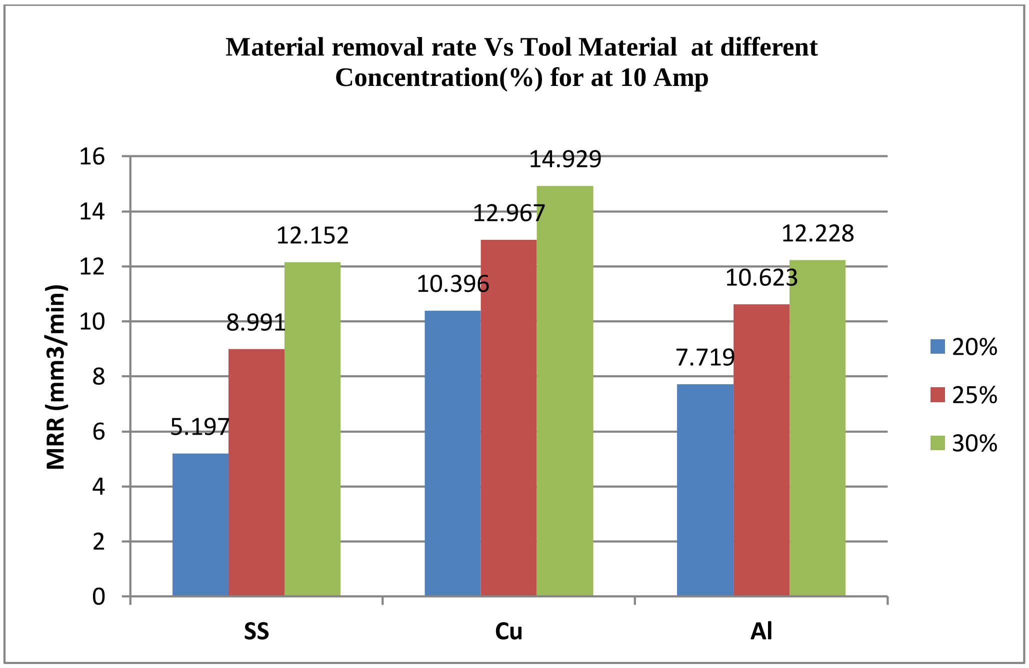

Fig. 2. Plot between Material removal rate Vs Tool Material at different Concentration (%) for at 10 Amp

From Table 3 it is observed that at 10 Amp current the MRR further increases for all the process parameters as compared to the 5 Amp current. Since MRR is directly proportional the current (I) so with increase in current keeping same electrode diameter, the current density will rise which will results increase in MRR.

CONCLUSIONS

1. From the present study it has been concluded that by the use of different electrolyte concentrations there is a change in material removal rate. It increases as electrolyte concentration increases.
2. Also by using various types of tools like stainless steel, aluminium and copper it affects the material removal rate. Out of which copper tool material showed good results as compared to the aluminium and stainless steel.
3. By increase in current density, the material removal rate is also increases. At 10 amp MRR is greater than at 5 amp for given tool material and electrolyte concentration.

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