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# INVESTIGATION OF PROCESS PARAMETERS ON ELECTROCHEMICAL MICRO MACHINING OF Cu-Zn-Sn ALLOY

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## ABSTRACT

Electrochemical micro machining (EMM) is one among the advanced manufacturing techniques to drill holes of minute sizes, especially drilling holes with a diameter of below 1 mm. EMM offers quite a few advantages that include superior machining rate, enhanced precision and control and a wider group of materials that can be machined. These are pretty tough to accomplish through conventional machining process. In this investigation, parametric study of EMM was conducted to congregate the requirements of proficient micromachining. Machining voltage, Electrolyte concentration, and Pulse on time are the key process parameters that are significant for EMM. Performance of micro machining was observed during material removal rate (MRR) and overcut. The outcome of this examination illustrated that machining voltage and electrolyte concentrations are very important in affecting the performance characteristics.

**Keywords:** electrochemical micro machining (EMM), material removal rate (MRR), overcut.

## INTRODUCTION

EMM is being used frequently, these days, in the micro machining of hard metals as excellent surface quality could be achieved with hard surfaces such as ceramics and high alloy steels etc. When weighed up with electrical discharge machining (EDM), electrochemical machining (ECM) causes neither electrode wear nor heat-affected zone. Of late, several R&D activities have revealed that EMM is a potential technique with flexibilities in micro electromechanical systems (MEMS) and in some advanced manufacturing domain. In comparison with contending technologies such as micro EDM, ion beam machining and laser beam machining, EMM has plenty of benefits such as high removal rate, very little or no wear in tool in the process, cost effectiveness and more importantly, it requires no special equipments. EMM is one of among the most commonly followed manufacturing techniques in electronics industry, aviation industry, automobile industry and in medical field as well for a range of applications that include fabrication of metallic parts, PCBs, semiconductor devices, cooling holes in jet turbine blades and in surgical implants.

B. Mallick *et al*. studied diverse process constraints such as electrolyte concentrations, applied voltage, pulse frequency and duty ratio on different machining performance characteristics like MRR, overcut and HAZ during micro-profile making on electrically non-conducting glass. They set the voltage, electrolyte concentration, pulse frequency and duty factor from 35-55 V, 10-30 wt%, 200Hz-1 kHz and 45-65% correspondingly for the period of his trialing. A cylindrical shaped stainless steel tool of diameter 350 µm was used and NaOH solution was used as an electrolyte to conduct the experiments. It was found that material removal rate was high for 55 V and 30 wt% electrolyte concentration respectively. Overcut and HAZ area decreased with frequency whereas they increased after 50% and 55% of duty ratio correspondingly [1].

Charanjit Singh Kalra *et al*. made an investigation on machining of micro-hole during electrochemical micromachining of stir-cast hybrid aluminium /(alumina + silicon carbide + carbon particulates) metal matrix composite. They developed an EMM set-up and used it for conducting the experimental investigation and selected supply current, supply voltage, pulse-on time, pulse-off time, electrolyte concentration and electrolyte flow rate as process parameters. The outcome of these parameters on MRR, electrode wear rate, surface roughness height, taper cut, over cut and micro-spark-affected zone were evaluated by plotting graphs. The end result proved that the MRR, EWR, TC, OC and MSAZ increased with an increase in supply current, voltage and pulse-on time. The most favorable parametric permutation for high MRR with low TC, OC, and MSAZ was found at 1.5 A supply current, 13 V supply voltage, 10 µs pulse-on time, 10 µs pulse-off time, 15 g/L electrolyte concentration, and 0.2 L/min electrolyte flow rate [2].

S. Dharmalingam *et al*. examined the power of the process factors such as electrolyte concentration, machining voltage, frequency on the over cut and MRR by Taguchi methodology and grey relational analysis. They discussed a method for optimizing the machining parameters on drilling of Al - 6% Gr Metal Matrix composites using EMM. By investigation, most favorable levels of parameters were found out and validated through confirmation tests. The confirmation outcome proved that there was reasonable improvement in MRR, Overcut and Grey relational grade. They were improved by 08.33%, 41.17% and 81.77% respectively. It was studied that the machining performance could be efficiently enhanced in relation to initial parametric setting. [3]

Alakesh Manna and Anup Malik ventured an attempt to discover the possibility to apply electrochemical machining technique to produce micro level drilled hole on Al/10vol%Al2O3-MMC. They built up an EMM setup and utilized it for experimental investigation and carried out different experiments to explore the power of the EMM parameters on the material removal rate and radial overcut. Experimental end result illustrated that the

machining voltage ranges from 5 to 10 volt would give a higher material removal when HCl is appended with NaCl electrolyte. And the MRR increased with a rise in machining voltage and concentration of NaCl electrolyte [4].

B.R.Sarkar *et al*. built up a second order, non-linear mathematical model for ascertaining the correlation among different machining parameters, like applied voltage, electrolyte concentration and inter-electrode gap with the principal machining process criteria, specifically MRR, radial overcut and thickness of HAZ during an ECDM procedure on silicon nitride. They developed this model depending on response surface methodology (RSM) by using relevant experimental data, which were acquired during the ECDM micro-drilling operation on silicon nitride ceramics. They also offered an analysis of variance (ANOVA) and a confirmation test to substantiate the fitness and adequacy of the developed mathematical models. From the parametric analyses based on mathematical modeling, it was recommended that applied voltage had more important consequences on MRR, ROC and HAZ thickness during ECDM micro-drilling process, comparing other machining parameters like electrolyte concentration and inter-electrode gap [5].

In our endeavor, we are venturing into the investigation of process parameters such as machining voltage, electrolyte concentration and pulse on time on EMM of 58.5% Cu-40% Zn-1.5% Sn alloy, especially on MRR and over cut.

## EXPERIMENTAL SETUP OF EMM

Figure-1 shows the trial set up of EMM in which a Tungsten tool of 300µm diameter was used to perform an end to end hole on a brass plate of 600µm thickness.

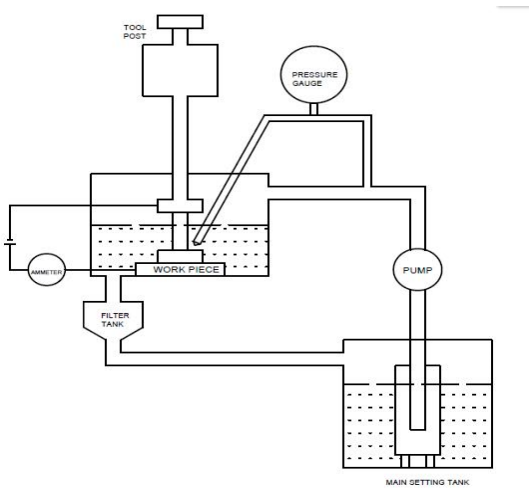


**Figure-1.** Electrochemical micro machine.

## RESULTS AND DISCUSSIONS

Experiments were performed on the EMM set-up to envisage the influence of input machining voltage, electrolyte concentration and pulse on time on MRR and over cut. Investigational outcomes have been plotted on graphs to exhibit the influence of above said process parameters on MRR and over cut.

## EFFECT OF MACHINING PARAMETERS ON MRR

### Effect of machining voltage on MRR

Figure-2 reveals that the material removal rate rises with voltage at a certain machining parametric combination, i.e. an electrolyte ($NaNO_3$) concentration of 25 g/l and a pulse on time of 50 µs. It was also studied that the MRR from 4 V to 5 V, 5 V to 6 V, 6 V to 7 V and from 7 V to 8 V are almost in similar pattern.

This could be attributed to the clean machining atmosphere without any presence of contamination in the electrolyte that prevailed during the micromachining.

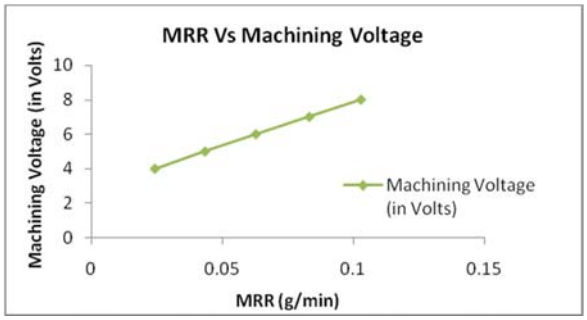


**Figure-2.** MRR vs machining voltage (Electrolyte concentration: 25 g/l &pulse on time: 50 µs).

### Effect of Electrolyte concentration on MRR

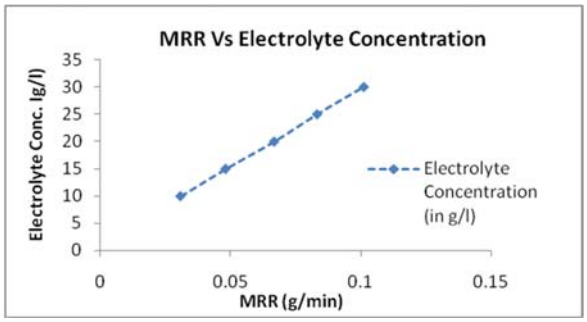


**Figure-3.** MRR vs Electrolyte concentration (Voltage: 7 V &pulse on time: 50 µs).

From Figure-3, it was noted that the effect of electrolyte concentration on MRR at a certain machining parametric combination, i.e. a machining voltage of 7 V and a pulse on time of 50 µs, is also identical to the graph plotted with MRR Vs Machining voltage. Here the MRR steadily rises with a rise in electrolyte concentration.

The steady rise in MRR could be attributed to the rise in machining current. The machining current increases at higher electrolyte concentrations because of the bigger number of ions associated in the machining with higher electrolyte concentrations.

**Effect of pulse on time on MRR**

Figure-4 embodies the effect of Pulse on time on the MRR at a certain parametric combination i.e., an electrolyte concentration of 25 g/l and a machining voltage of 7 V. From the graph it is quite obvious that a rise in pulse on time leads to a rise in MRR.

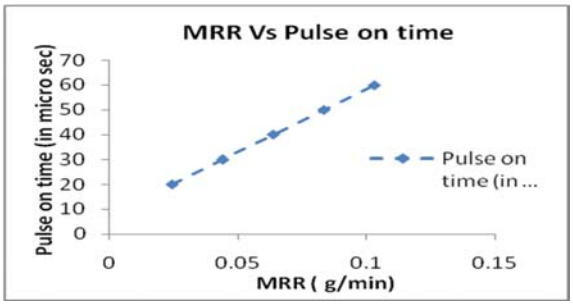


**Figure-4.** MRR vs pulse on time (Electrolyte concentration: 25 g/l, Voltage: 7 V).

Rise in pulse on time means that more time is allowed for machining the work, because only during pulse on time, the actual material removal takes place. Hence, with the increase in pulse on time, average current density increases and in turn, leads to the increase in MRR.

## EFFECT OF MACHINING PARAMETERS ON OVERCUT

**Effect of machining voltage on over cut**

In order to measure machining accuracy, the over cut phenomenon has to be considered. It is evident from Figure-5 that over cut rises with the rise in machining voltage. When the machining voltage increases, current flux flow dips because of the localization effect. As there is less localization effect, the drifting current flow actually increases in the micromachining zone and consequently it is affecting more material removal from the bigger area of work piece that causes a rise in over cut. At voltages more than 7 V, over cut phenomenon is more predominant as electrochemical reactions produce $H_2$ gas at micro-tool and the gas bubbles rupture down leading to the event of micro-sparking.

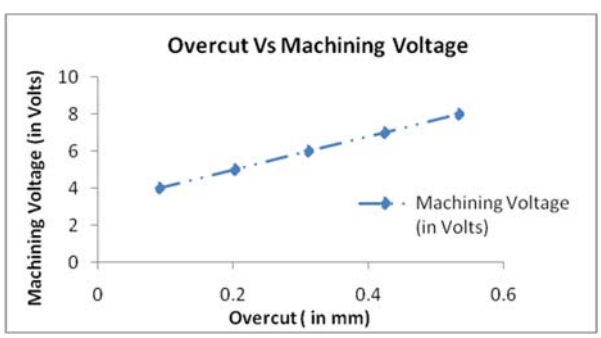


**Figure-5.** Over cut vs machining voltage (Electrolyte concentration: 25 g/l, pulse on time: 50µs).

This sparking causes unrestrained material removal from the work piece and eventually ends up with larger over cut. Hence, the over cut increases more rapidly at higher voltages.

**Effect of Electrolyte concentration on over cut**

Figure-6 illustrates the effect of electrolyte concentration on over cut at a certain machining parametric condition, i.e., a machining voltage of 7 V and a pulse on time of 50 µs. As there is a rise in electrolyte concentration, ions related with the machining operation in the machining area is also on the rise. More agglomeration of ions diminishes the reactions of localization effect of electrochemical material removal. This tends to witness higher over cut of the brass material and thus reduces the machining accuracy.

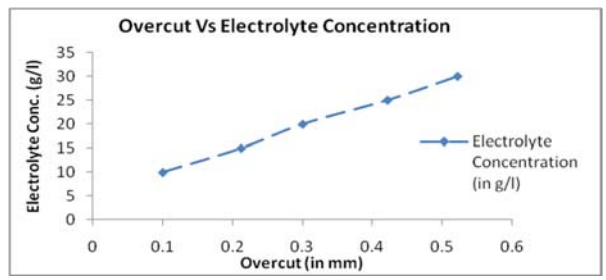


**Figure-6.** Over cut vs Electrolyte concentration (Machining voltage: 7 V, Pulse on time: 50µs).

Moreover, the comparatively larger agglomeration of electrolyte also leads to a rise in the current density and in turn, results in bigger over cut. The stray current effect increases because of the rise in machining voltage and the electrolyte concentration. Due to this fact, the contour of the drilled hole is almost circular.

**Effect of pulse on time on over cut**

Figure-7 proves that the over cut increases as pulse on time increases at a certain machining parametric combination, i.e., a machining voltage of 7 V and an electrolyte concentration 25 g/l.

More the pulse on time, the average current would also be higher. For higher current, the localization effect gets reduced and in turn, increases the over cut.

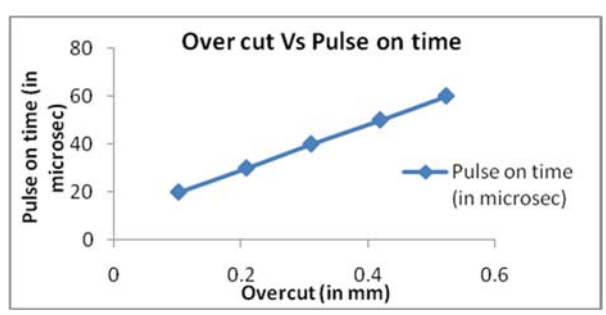


**Figure-7.** Over cut vs pulse on time (Machining voltage: 7 V, Electrolyte concentration: 25 g/l).

## CONCLUSIONS

This research work took up some key process parameters like Machining voltage, Electrolyte concentration and Pulse on time and they have been deemed to examine the influence on the MRR and over cut. A machining voltage range of 4 V to 8 V has given an considerable amount of MRR at modest accuracy. And the most efficient region of pulse on time and electrolyte concentration could be deemed as 20 µs to 60 µs and 10 g/l to 30 g/l respectively. These parametric conditions have given us an appreciable quantity of MRR and over cut. From the graphs, it could be inferred that a lower value of electrolyte concentration with higher machining voltage and modest value of pulse on time will generate less over cut at modest MRR for electrochemical micromachining of brass.

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