EXPERIMENTAL STUDY ON ELECTROCHEMICAL MACHINING OF HIGH CARBON HIGH CHROMIUM DIE STEEL

B.Iniyaraja¹, A.Sivalingam², S.Mahalingam³, R.Sathish⁴
¹,²,³Dept. of Mechanical Engg., Sona College of Technology, Salem
⁴Dept. of Mechanical Engg.,Sona College of Technology, Salem
e-mail:iniyaraja5014@gmail.com

ABSTRACT

ECM is one of the most exclusively used nontraditional machining processes for machining of materials with high hardness and poor machinability. However, there is a critical need for exploration of the application of ECM in cost effective machining of relatively harder materials such as high carbon high chromium die steel, stainless steel and super alloys. High carbon high chromium die steel belongs to that class of high hardness material (63 HRC) whose use has been ever increasing since last few decades. This work deals with the effect of Silver Nitrate solution (AgNO₃) on Material Removal Rate (MRR) of high carbon high chromium die steel by ECM. In addition to analyze the effects of influencing factors on High carbon high chromium die steel for finding the optimum parameters. Four different process parameters were undertaken for this study: applied voltage, tool feed rate, electrolyte discharge rate and three types of electrolyte solution. The effects of AgNO₃ mixed NaNO₃ aqua solution on the work piece are studied and the relationship among the variables have been determined for achieving maximum MRR. AgNO₃ - N/50 mixed NaNO₃ aqua electrolyte solution presented the better results of the MRR, in Electrochemical Machining of High Carbon High Chromium Die Steel.

Keywords- ECM, MRR, High carbon high chromium die steel, AgNO₃

INTRODUCTION

ECM is similar to electro polishing where there takes place an electrochemical anodic dissolution process in which a direct current with high density and low voltage is passed between a workpiece and a pre-shaped tool (the cathode). At the anodic surface, metal is dissolved into metallic ions by the depleting reaction, and thus the tool shape is copied into the workpiece. Because no forces exist between the workpiece and tool, holes at virtually any angle can be machined into extremely hard materials. ECM can be applied to any electrically conductive material regardless of its hardness. There is no need to use a tool made of a harder material than the workpiece. The hardness of the workpiece is not a hindrance for the use of ECM to machine them. Further, ECM is able to produce smooth, stress free and crack free surfaces. ECM is an imaging process, where the cathode tool moves with a certain feed rate towards the workpiece and its negative mirror shape is reproduced in the workpiece. (E.g. aerofoil). Recent advances lie in computer-aided tool design, and the use of pulsed power, which led to greater accuracy for ECM-produced components. [1-4,7].
The industrial sectors utilizing ECM technology fall into six main categories such as tool and die, automotive, aerospace, power generation, oil and gas industries and medical applications. For example,[5]

- The tight tolerance turbine blades and dies for automobile sector were machined by using ECM.
- It is mainly used in the manufacture of dies, which is involved in producing plastic components.
- ECM provides a high-quality, efficient method for producing aerospace components.
- Manufacturing of axial flow turbine blades and axis symmetric turbine nozzles from extremely difficult to machine material like Inconel® 718 & 625.
- The creation of internal helical splines in bores of various sizes and lengths for medical and process system applications.
- Electrochemical deburring is a fast process; typical times for smoothing the surfaces of manufactured components are 5 to 30.

The parameters that influence the process of ECM are voltage, current, IEG (Inter Electrode Gap), tool feed rate, electrolyte discharge rate, types of electrolyte, electrolyte concentration, electrolyte conductivity and electrolyte temperature.[6-10]

II. EXPERIMENTAL SETUP

The experimental setup includes an ECM 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 electrolytes used are 15% Plain NaNO$_3$ and AgNO$_3$ (N/10) & AgNO$_3$ (N/50) aqua solution (15 kg of salt in 100 litres of water and 500 ml of AgNO$_3$- N meant Normality of Solution). The electrolyte is filled in the electrolytic tank and is supplied to the machining unit through a pump. A digital rotameter is employed to measure the discharge rate of the electrolyte. Copper has been used as an electrode and the pressurized electrolyte passes through the electrode. The setup is shown in figure 1.

Fig.1 ECM set up

The machining unit includes a spindle through which the electrode is inserted. The workpiece 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 (IEG) is accurately set by touching the electrode and then feeding the electrode in reverse direction for the specified time. Then the machining was done for the set values. The performance of ECM of High carbon high chromium die steel is found in terms of material removal rate.

III. HCHCDS– PROPERTIES

For this project, High carbon High Chromium Die Steel (HCHCDS) is selected as a workpiece. Being a Die tool steel its hardness is very high (63 HRC) such that it is very difficult and uneconomical to
machine it using any traditional machining process. But ECM could be an effective means to machine it.

IV. SUMMARY OF WORKING CONDITIONS

<table>
<thead>
<tr>
<th>TABLE 2 Complete working conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage (V)</td>
</tr>
<tr>
<td>Current (A)</td>
</tr>
<tr>
<td>Current density (A/cm²)</td>
</tr>
<tr>
<td>Inter electrode gap (mm)</td>
</tr>
<tr>
<td>Feed rate (mm/min)</td>
</tr>
<tr>
<td>Power supply – DC</td>
</tr>
<tr>
<td>Electrolyte discharge rate (lpm)</td>
</tr>
<tr>
<td>Electrolyte types</td>
</tr>
<tr>
<td>Electrolyte concentration</td>
</tr>
<tr>
<td>AgNO₃Quantity mixed</td>
</tr>
<tr>
<td>Toolmaterial</td>
</tr>
<tr>
<td>Toolouterdiameter</td>
</tr>
<tr>
<td>Electrolyte temperature</td>
</tr>
</tbody>
</table>

Work piece | High carbon high chromium die steel |
Workpiece hardness | 63 HRC |
Machining time (min) | 3 |

V. SELECTED TOOL GEOMETRY

The tool was made of electrolytic copper with 24.5 mm as outer diameter which is shown in figure 2. The experiments were conducted by using the copper for three minutes and the results were recorded.

![Selected tool geometry](image)

VI. DESIGN OF EXPERIMENTS

Initially trial experiments were conducted for various values of voltage, tool feed rate, electrolyte discharge rate and IEG to determine the major influencing parameters, from among the listed. Based on the results of trial experiments, the following major intervening variables affect the objectives of ECM:

- Applied Voltage
- Tool feed rate
- Electrolyte discharge rate
- Inter Electrode Gap (IEG)
- NaNO₃, AgNO₃ (N/10 & N/50) mixed NaNO₃ aqua solutions
Full Factorial DoE is selected for finding the individual and interaction effects among the major intervening variables. The experiments were conducted based on the DoE for NaNO₃, AgNO₃ (N/10 & N/50) mixed NaNO₃ aqua solutions and the results were recorded. Mini Tab statistical software is used for finding the DoE table.

Fig 3. MINITAB 13 – Design of Experiments Window

A. Tabulation

The following tables show the values of before machining, after machining, MRR and energy consumed for removal of material from the workpiece. [6,10]

Material removed = Before machining – After machining (g)
Material Removal Rate (MRR) = Material removed * 1000 (mm³/min)

= \frac{\text{Density of Material (7.8 g/cc) \times Time (3 minutes)}}{	ext{Material removed \times 1000 (mm³/min)}}

Sartorius electronic weighing machine with 1mg accuracy were used for measuring material removal rate.

VII. RESULTS AND DISCUSSION

The effects of NaNO₃, AgNO₃ (N/10 & N/50) mixed NaNO₃ aqua solutions on the material removal rate of the Electrochemical machining of High carbon high chromium die steel with a stationary tool have been studied.

A. Effect of tool feed rate on MRR at 12 Voltage and 8 lpm

Figures 4–6 show the effect of tool feed rate on the material removal rate at different voltage with the discharge rate of 8 lpm. The results obtained in the experiments reveal that the effect of Silver nitrate solution with normality 50 (N/50) on the MRR is significantly than N/10 or plain solution of Sodium nitrate. From figure 4, it is observed that AgNO₃ (N/50) mixed NaNO₃ electrolyte solution presented the better results at higher feed rate condition.

It is observed that material removal rate increases with the increase of feed rate while using AgNO₃ (N/50) mixed NaNO₃ electrolyte solution. When the dissolution of workpiece not equal to the tool feed rate, there is a possibility of touching the tool with the workpiece results short circuit. So only
minimum amount of material removal or, no chance of removal of material from the workpiece. This facilitates, analyze the suitable parametric combinations that can be made for achieving better material removal rate.

B. Effect of tool feed rate on MRR at 15 Voltage and 8lpm

Generally tool feed rate is one of the major intervening variables of Electrochemical Machining and the effect of tool feed rate at 15 voltage and 8 lpm conditions is shown in fig. 5. Here, also AgNO₃ (N/50) mixed NaNO₃ solution given the better MRR than other electrolyte combination. The maximum MRR of 229 mm³/min achieved at 15 V, 0.54 mm/min and 8 lpm.

C. Effect of tool feed rate on MRR at 18 V & 8 lpm

The maximum MRR of 410 mm³/min is obtained at the conditions of 18 V, 0.54 mm/min and 8 lpm. Based on the experimental results reveal that the MRR increases with the increase of tool feed rate in AgNO₃ (N/50) mixed NaNO₃ solution. It is observed from figure 6 that higher voltage and feed rate yield the higher MRR than the lower conditions.

D. Effect of tool feed rate on MRR at 12 Voltage and 10 lpm

Figures 3.7 – 3.9 show the effect of tool feed rate on the material removal rate at different voltage with the discharge rate of 10 lpm. The results obtained from the figure 7 reveal that the effect of Silver nitrate solution with N/50 on the MRR is very considerable at higher feed rate condition.

E. Effect of tool feed rate on MRR at 15 Voltage and 10lpm

From the figure 8, it is noted that AgNO₃ - N/50 and N/10 mixed NaNO₃ solution gives the better results on MRR than the plain NaNO₃ aqua
solution. The maximum MRR is achieved at 0.54 mm/min using AgNO₃ (N/50) mixed NaNO₃ solution.

Based on the experimental results, it is notified that AgNO₃ (N/50) mixed NaNO₃ solution performs in the better way to achieve the MRR at all feed rate and voltage conditions. The maximum MRR is fallen at 0.54 mm/min of tool feed rate with 18 voltage condition.

**F. Effect of tool feed rate on MRR at 18 V & 10 lpm**

Fig 9. Effect of Tool feed rate on MRR at 18 V & 10 lpm

The MRR increases with feed rate at all feed rate condition while using Plain NaNO₃ and AgNO₃ (N/50) mixed solutions. But performance of AgNO₃ (N/10) mixed solution not performs in a stable manner on MRR.

**G. Effect of tool feed rate on MRR at 12 Voltage and 12 lpm**

Fig 10. Effect of Tool feed rate on MRR at 12 V & 12 lpm

Figures 10 – 12 show the effect of tool feed rate on the material removal rate at different voltage with the discharge rate of 12 lpm. The results obtained from the figure 10 reveal that the effect of Silver nitrate solution with N/50 on the MRR is very significant at higher feed rate condition. But the effect of AgNO₃ - N/10 mixed with NaNO₃ aqua solution on the MRR is not significant at the conditions of 12 voltage and 12 lpm.

**H. Effect of tool feed rate on MRR at 15 Voltage and 12 lpm**

Fig 11. Effect of Tool feed rate on MRR at 15 V & 12 lpm

The MRR increases with feed rate at all feed rate condition while using Plain NaNO₃ and AgNO₃ (N/50) mixed solutions. But performance of AgNO₃ (N/10) mixed solution not performs in a stable manner on MRR.
I. Effect of tool feed rate on MRR at 18 V & 12 lpm

From the figure 12, it observed that the maximum MRR of 290 mm³/min has been obtained at the conditions of: Tool feed rate of 0.54 mm/min, 18 voltage with 12 lpm as discharge rate.

Based on the experimental results reveal that the AgNO₃ (N/50) mixed NaNO₃ solution presented the better MRR when compare with the other electrolyte combinations. The effect of AgNO₃ (N/50) mixed NaNO₃ solution on the MRR is very significant at higher feed rate and higher voltage conditions.

VIII. CONCLUSION

In this work, experimental investigations have been made to study the effects of AgNO₃ mixed NaNO₃ electrolyte aqua solution on the material removal rate in Electrochemical Machining of High carbon high chromium die steel. The major influencing parameters have been obtained for achieving maximum material removal rate by using the AgNO₃ mixed NaNO₃ electrolyte solution. Based on the results obtained in this experiment, the following conclusions are drawn.

- AgNO₃ mixed NaNO₃ electrolyte aqua solution presented the better MRR at higher voltage and higher feed rate conditions.
- AgNO₃ mixed NaNO₃ electrolyte aqua solution enhancing the MRR because of the electrical conductivity of Silver. But consumption of energy is higher than the other solutions for removal of material from workpiece. The significant effect of AgNO₃ mixed NaNO₃ electrolyte aqua solution on MRR is considerable.
- The full factorial experiments used in the present work has proved its adequacy to be an effective tool for the analysis of the ECM process.
- AgNO₃ mixed NaNO₃ electrolyte aqua solution presented better results of material removal is insignificant.

IX. REFERENCES


