A Review Paper on Electro Chemical Discharge Machining Technique

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Abstract: Electrochemical Micro Machining (ECMM) and Electric Discharge Micro Machining (EDMM) processes have high potential when applied in micro regime for good accuracy and shape reproduction. But they have a limitation that only electrically conducting materials can be machined by them. To overcome this limitation, a combination of ECMM and EDMM processes has been conceived, and it is known as “electrochemical spark micro machining” (ECSMM) / “electro chemical discharge machining” (ECDM). Electro Chemical Discharge Machining (ECDM) is a controlled metal-removal process which is used to remove the metal by means of electric spark erosion. In this process an electric spark is used as the cutting tool to cut (erode) the work piece to produce the finished part to the desired shape. There are various ECDM process parameters (variables) on which the machining performances depends such as these parameters are polarity, peak current, pulse on time, pulse off time, flushing pressure, Voltage and Concentration. This paper reviews the vast array of research work carried out within past decades for the development of ECDM.

Keywords: Electrical Chemical discharge machining, ECDM parameters, machining characteristic

1. Introduction

Electro chemical discharge machining is Non conventional machining process which is used for micro fabrication. The principle of ECDM is to use the eroding effect of controlled electro Chemical discharges machining on the electrodes. The metal-removal process is performed by applying a pulsating (ON/OFF) electrical charge of high-frequency current through the electrode to the work piece. This erodes very tiny pieces of metal from the work piece at a controlled rate. It is thus a thermal erosion process. The sparks are created in a dielectric liquid generally water or oil, between the work piece and an electrode, which can be considered as the cutting tool. There is no mechanical contact between the electrodes during the whole process. Since erosion is produced by electrical discharges, both electrode and work piece have to be electrically conductive. Electro chemical spark machining (ECSM) is also a hybrid machining process which is combination of Electrochemical machining (ECM) & Electro discharge machining (EDM) which is also known as, Electrochemical Engraving, Electrochemical Discharge Machining etc.

Figure 1: Evolvement of ECS (Branch in the Classification Tree of Manufacturing Process)
The reactions of electrochemical type at electrolyte – anode border are reason for production of oxygen and dissolution of anode.

\[
\begin{align*}
\text{Cu} & \rightarrow \text{Cu}^{2+} + 2e^- \\
2\text{H}_2\text{O} & \rightarrow \text{O}_2 \uparrow + 4\text{H}^+ + 4e^-
\end{align*}
\]

Here, oxygen gas evolves at the anode sparking occurs across the oxygen gas bubble at the interface of the anode and electrolyte and oxygen gas develops at the anode.

(b) Reactions at cathode and electrolyte interface

Following electrochemical reactions take place at electrolyte interface – cathode, and also reason for production of hydrogen gas.

\[
\begin{align*}
\text{Cu}^{2+} + 2e^- & \rightarrow \text{Cu} \\
2\text{H}^+ + 2e^- & \rightarrow \text{H}_2 \uparrow \\
\text{Na}^+ + e^- & \rightarrow \text{Na} \\
2\text{Na} + 2\text{H}_2\text{O} & \rightarrow 2\text{NaOH} + \text{H}_2\uparrow \\
2\text{H}_2\text{O} + 2e^- & \rightarrow \text{H}_2\uparrow + 2\text{OH}^-
\end{align*}
\]

Hydrogen gas produced at the cathode causes sparking across the bubbles between the electrolyte and cathode.

In ECSM process generally two electrodes are largely different in size. Machining may takes place at cathode and anode. The electrode which is used as tool is called active electrode and which is small in size compared to another electrode, which is called as auxiliary electrode. Work piece is kept near to active electrode. Here, voltage applied is also large. Due to small shape at active electrode there is large current density so large amount of gas is generated there. This gas is nonconductive in nature. So this gas film acts as high resistance for electric current so ohmic heating also takes place & more number of gas bubbles are generated this gas is passivate active electrode. As applied voltage is above break down voltage of gas film there is occurrence of spark. Due to this spark gas layer break down takes place & again electrochemical reaction starts. This process continues. Generally power applied in pulsed form of micro second range. This process is shown by operation flow of ECSM.

2. Mechanism of generation of spark in electrolyte

(a) Reactions at anode and electrolyte interface

(b) Reactions at cathode and electrolyte interface

Figure 2: a) and (b) Hole entrance and exit drilled at 35V$^3$

(c) and (d) Hole entrance and exit drilled at 30V$^3$

Figure 3: Schematic of diagram ECSM

Figure 4: Operational flow of ECSM process showing intermediate processes
Electro chemical spark machining basically two types. First when cathode is used as electrode then it is called as ECSM direct polarity (ECDP) and when anode is used as tool then it is called as ECSM reversed polarity (ECRP). In both case work piece to be machined is kept near active electrode. Following table compare ECDP & ECRP.

<table>
<thead>
<tr>
<th></th>
<th>ECDP</th>
<th>ECRP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cathode</td>
<td>Active Electrode (small Size)</td>
<td>Auxiliary electrode (large in size)</td>
</tr>
<tr>
<td>Anode</td>
<td>Auxiliary electrode (large in size)</td>
<td>Active electrode (small in size)</td>
</tr>
<tr>
<td>Surface finish</td>
<td>Better than ECRP</td>
<td>Good</td>
</tr>
<tr>
<td>Passive gas</td>
<td>Hydrogen</td>
<td>Oxygen</td>
</tr>
<tr>
<td>MRR</td>
<td>Good</td>
<td>Better than ECDP</td>
</tr>
</tbody>
</table>

3. Major Parameters of ECDM

EDM Parameters mainly classified into two categories.
They found that the current intensity of the EDM process to machining of precise cylindrical forms on hard and difficult-to-machine materials [P. Matoorian, S. Sulaiman, Ahmed et al.] proved that large current intensity would result in higher material removal rate. Matoorian et al. presented the application of the Taguchi robust design methods to optimize the precision and accuracy of the EDM process for machining of precise cylindrical forms on hard and difficult-to-machine materials [P. Matoorian, S. Sulaiman, Ahmed et al.]. They found that the current intensity of the EDM process affects the material removal rate greatly. Muthuramalingam and Mohan developed Taguchi-DEAR methodology based optimization of electrical process parameters [T. Muthuramalingam, B. Mohan, et al.]. Tzeng and Chen described about the application of the fuzzy logic analysis coupled with Taguchi methods to optimize the precision and accuracy of the high speed electrical discharge machining process [Y. F. Tzeng, F. C., et al.]. The most important factors affecting the precision and accuracy of the high speed EDM process have been identified as duty cycle and peak current. Kuriakose and Shunmugam developed a multiple regression model to represent relationship between the input and output process variables [S. Kuriakose, M. S. Shunmug, et al.]. They have done the multi objective optimization method based on

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<table>
<thead>
<tr>
<th>Author/year</th>
<th>Process parameters</th>
<th>Tool electrode</th>
<th>Work piece</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ming, Q.Y.et al.(1995)</td>
<td>Current pulse width, pulse interval, Additives powder concentration</td>
<td>Copper</td>
<td>High carbon steel</td>
</tr>
<tr>
<td>Tzeng, Y.F. et.al(2005)</td>
<td>Peak current pulse duty cycle powder size, powder concentration of Al, cr, cu, si.</td>
<td>Copper</td>
<td>SKD-11</td>
</tr>
<tr>
<td>Kansal H.K. et.al(2007)</td>
<td>Peak current, Pulse on time, Pulse off time, concentration of powder, Grain &amp; Nozzle.</td>
<td>Copper</td>
<td>AISI D2 Die steel</td>
</tr>
<tr>
<td>Syed &amp; palaniyandi(2012)</td>
<td>Peak current, pulse on time , polarity, concentration of Al powder.</td>
<td>Electrolytic copper</td>
<td>W300 die steel</td>
</tr>
</tbody>
</table>
non-dominated sorting genetic algorithm to optimize the EDM process parameters.

6. Conclusion

ECDM is very good process that can be applied to metal, ceramic, composite and non-conductive material. It has less MRR but that is advantage during micromachining. Main obstacle to apply ECDM to miniature component is crack near machining. MRR is also dependent on many parameters. To increase reproducibility of ECDM, there is need of research to control over gas film during dynamic conditions of machining. This process has potential to heat treatment also. Comparing to another non-conventional process it has less setup cast, so by proper modification it can become practical machining process.

References