Journal of Advances in Science and Technology
Vol. 13, Issue No. 01, (Special Issue) March-2017, ISSN 2230-9659

Effect of Electrolyte Solution on Various Parameters in ECDM

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Abstract – The performance of ECDM, in terms of material removal rate and rate of machining, is affected by many factors. Relationship between these factors and machining performance are highly non- linear and complex in nature. Therefore it is very difficult to develop a relationship between these factors and the machining performance with conventional mathematical modeling. Electrolyte solutions are one of the major parameters that have to be considered for determining the effectiveness of ECDM process.

Keywords – ECDM, Machining Performance, electrolyte solution, Conventional modelling, Parameters

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INTRODUCTION

Any new technology requires new machining skills. In the last century, the need for using more and more specialized materials (e.g. silicon, composites or ceramics) greatly increased the already large arsenal of machining technology. The last century also saw the birth of micromachining, in particular micromachining of silicon. At present huge variety of micromachining is available for silicon. Similar situation exists for electrically conductive materials, wherein particular electrochemical machining (ECM) and electrical discharge machining (EDM) are two powerful tools available. However several electrically non- conductive materials are also of great interest for many applications. Glass and composite materials are two such examples. The technical requirements for using glass in micro system are growing. Medical devices requiring biocompatible materials are only one amongst many examples.

Electro-Chemical Discharge Machining

Ceramics (glass) and plastic materials are playing vital role in the process industries. Electrochemical Discharge Machining (ECDM) is the means to obtain absolute machining parameters using advanced materials until recently. Electrochemical Discharge Machining (ECDM) is newly developed hybrid process that combines both ECM and EDM (ECM + EDM = ECDM). It has been successfully used for machining electrically non-conductive advanced engineering materials such as glass and ceramics which has shown the possibility of drilling micro-holes by smaller electrodes efficiently and economically [1].

It has been found that the advanced materials are difficult to machine by conventional machining processes [4]. It is no longer possible to produce parts with better surface finish, close tolerances and complex shapes in advanced materials by conventional machining methods. To machine difficult to difficult materials, some non-traditional procedures, like laser machining or ultrasonic machining may be integrated to become a composite machining procedure. So far, it still needs more study for machining of non-conductive brittle materials since it has become key materials in the micro-electro mechanical system (MEMS) field. For example, the glass or quartz is usually bonded with semi-conductive material due to its transparency, chemical resistant properties and so on. Likewise the engineering ceramic is also used often in the high-tech apparatus.

PRINCIPLE OF ECDM

An electrochemical discharge phenomenon is clearly demonstrated by following simple experiment. Two electrodes are dipped inside an aqueous electrolyte. Cathode is chosen with much smaller surface than the anode. When DC voltage is applied, electrolysis takes place and hydrogen gas bubbles are formed at tool- electrode (cathode) while as oxygen bubbles are formed at auxiliary electrode (anode). When the voltage is increased, current density also increases and more and more bubbles grow forming a bubble layer around the electrodes. When the voltage is increased above critical voltage, bubbles coalesce into gas film around the tool-electrode. Sparking phenomena is observed in the film where electrical discharges take place between the tool-electrode and surrounding electrolyte solution. Similar behavior can be observed by inverting the polarity and by changing the electrolyte, following fig1, explains ECDM phenomenon.

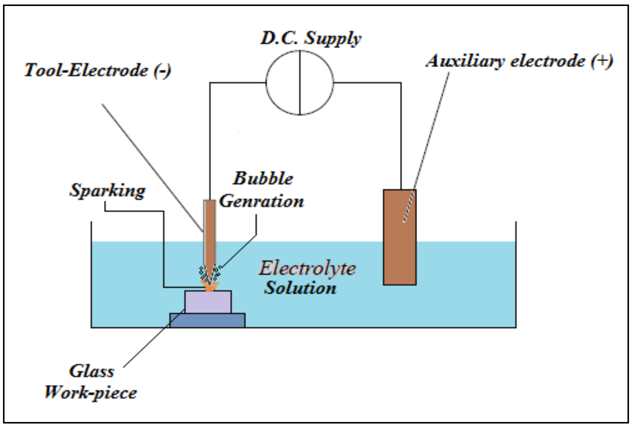
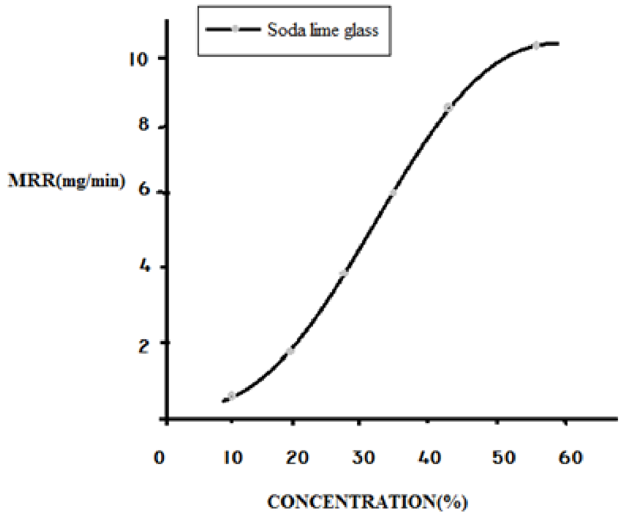


Fig.1 Principle of ECDM process

EFFECT OF ELECTROLYTE SOLUTION

Effect of electrolyte concentration on work piece material

Previous authors have proposed a thermal model to analyze the effect of electrolyte concentration and energy partition over material removal rate by finite element method. It was observed that with increase in electrolyte concentration from 10% to 30% increase in duty factor and increase in energy partition, material removal rate significantly increases especially in soda lime glass, while machining Al_2O_3 similar trend had been observed with low variation in results due to its high hardness at elevated temperature. Surface texture obtained is dependent on the concentration of electrolyte used i.e. its viscosity. For high electrolyte concentration however, cracks may form on the machining surface. The transition voltage adopted decreases with increase in electrolyte concentration. At higher electrolyte concentration, the amount of conductive ions was greater and thus the electrolysis rate became faster. By increasing the electrolyte concentration, an insulated gas film of a dense and complete structure could be rapidly formed to achieve stable discharge.



Graph 1.Effect of electrolyte concentration on material removal rate.[5]

Graph1 shows that MRR using present model goes on increasing from 10% concentration to 30% concentration significantly and there after the concentration does not play any role to enhance the MRR. This can be explained from the fact that as concentration is increased, the critical voltage and critical current increases. An increase in electrolyte current would mean accelerated electrolysis process. It would result in greater rate of hydrogen bubbles at cathode tool. The increased rate of hydrogen bubbles at cathode implies enhanced rate of sparking and hence higher MRR. When concentration is increased beyond 30%, specific conductance of electrolyte decreases and change in the voltage and current across the electrolyte is almost negligible. Since heat energy developed from the spark is proportional to the critical voltage and current, the material removal will be less at higher values of concentration.

Effect of thermal discharging on work-piece material:

Previous authors have investigated that the heat produced during electrochemical discharging phenomenon is able to melt glass. The most admitted hypothesis about the machining mechanism is that the machining is a thermal one. It is assumed that the work-piece surface is intensively heated leading to melting and may be even vaporization of the work material. Several experimental evidences confirm the thermal mechanism in machining. It is known that the tool electrode may reach temperatures up to 650°c

Kulkarni et al. showed by various measurements that after each current peak, i.e. each discharge, the temperature of the work-piece increases above the melting temperature and sometimes even above the vaporization temperature of the machined material. They estimated that about 77-96% of the energy supplied to the process is used to heat the electrolyte and only 2-6% is used for heating up the work-piece. Another experimental evidence for thermal

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mechanism in machining is the various observations of thermal cracks inside the machined materials which are seen mainly during high voltage machining. The dominant mechanism in machining is local heating of the work-piece by the electrochemical discharge. Another contributing effect is chemical etching of the work-piece, a mechanism that is accelerated by the local high temperature.

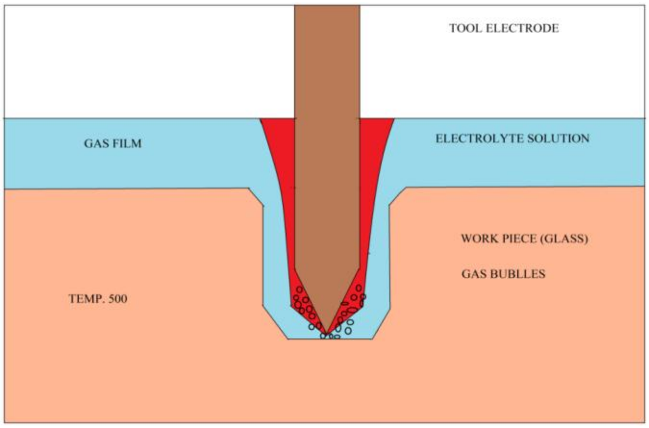


Fig.3.Thermal discharging process

Processes including glass machining seems to indicate that the temperature in the machining zone is quite low (500°C-650°C), a temperature at which glass still has quite a high viscosity. The material removal mechanism for glass machining is shown in fig.3. The electrochemical discharges heat up the work-piece locally, which results in lowering of the viscosity of glass and enhancing of chemical etching by OH radicals from the electrolyte. A zone of glass with lowered viscosity and electrolyte salt forms in front of tool electrode. (Water evaporates at that temperature).

As the electrochemical discharges are the heat source, machining at low and high depths will be very different. With increasing depth, it will be more difficult to the electrolyte to flow to the tip of the electrode (especially in case of micro hole drilling), which results in reduced discharge activity. Chemical etching will also be reduced. Both effects result in significant lowering of material removal rate. Therefore, the material removal rate is a function of machining depth. The first case is machining at low depths which is defined as the case where machining is limited by the heat propagation inside the work piece. The second case is machining at high depths, where machining is limited by leakage of the electrolyte at the machining zone and the difficulty in removing the machining materials from it.

Machining at low depths:

When machining a work-piece using electrochemical discharge at low depths, the electrolyte can reach the machining zone without difficulty. The electrochemical discharge takes place almost similar to a case where no work-piece is present but as soon as the machining temperature is reached, material is removed by melting and/or chemical etching. For simplification, we consider that the limiting mechanism for machining is the heat propagation in the work-piece (i.e. material removal itself is very fast).

Machining at high depths:

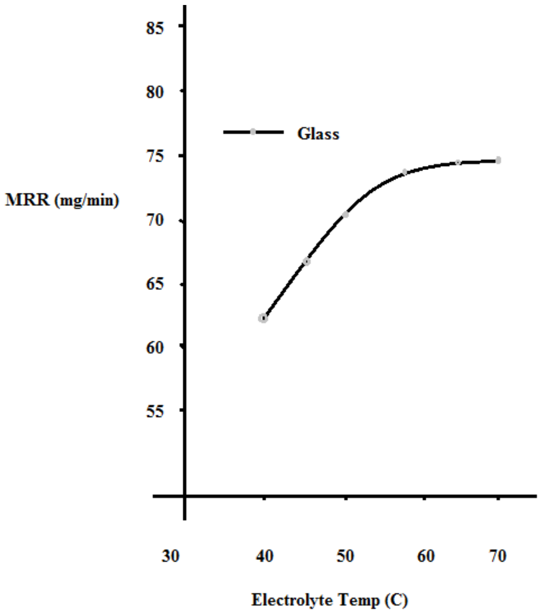
While machining at high depths, the electrolyte cannot reach the machining zone as easily as in the case of low depths. As a consequence material removal by chemical etching or melting of work-piece is lowered. The process is mostly limited by ability to bring the electrolyte to the machining zone and to remove the machined material out of this zone, both of which are highly geometry dependent aspects.

Effect of electrolyte temperature on material removal rate

When electrolyte temperature increases electrolyte conductivity increases too, thus increasing the amount of current which accelerates the electrolysis process, resulting in a greater rate of evaluation of hydrogen gas bubbles at the cathode. The increased rate of formation of gas bubbles at the cathode leads to an enhanced rate of sparking, hence higher material removal. So it can be said that material removal increases with increased conductivity.

Effect of electrolyte temperature on glass:

A graph, relating the electrolyte temperature and material removal; at 55v while machining glass is shown in graph 2.It is evident from the graph that as the electrolyte temperature increases the material removal also increases. It is also found that there is decreasing trend in material removal beyond a certain value of temperature. Due to high temperature, water evaporation increases the conductivity of electrolyte beyond some point starts decreasing; hence material removal also starts decreasing. On the other hand, the addition of electrically non-conducting debris contributes to a decrease in the electrolyte's electrical conductivity. The overall effect is that material removal decreases beyond a certain temperature of electrolyte.

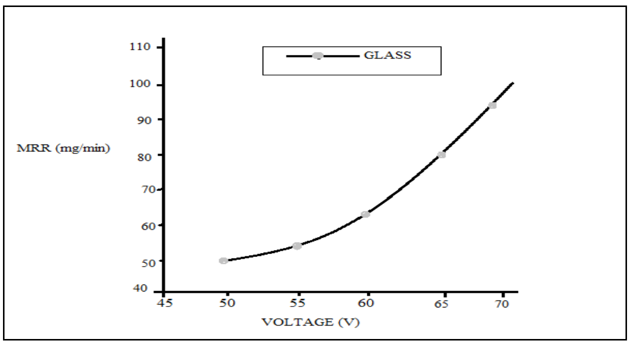


Graph 2.Effect of electrolyte temperature on MRR.[6]

The change in electrolyte conductivity, due to change in temperature and the addition of debris to the electrolyte, seem to be responsible for this behavior to, as explained in the preceding paragraph. Further after machining for a certain period of time, the sparking may not take place at some inter spaces.

***Effect of supply voltage on material removal rate*:**

It was observed that the volume of the material removed increases with increase in supply voltage. This is due to a large number of hydrogen bubbles evolved at the cathode at higher value of supply voltage. The energy content of a spark at higher potential gradient across a bubble is higher, resulting in removal of more amount of material by melting or vaporization of work-piece material in the vicinity of the spark. Hence, material removal rate increases at higher voltage.



Graph 3. Effect of supply voltage on material removal rate. [6]

Effect of voltage on glass

Graph 3 shows that the reason behind increase in supply voltage implies increase in discharge energy, hence higher temperature results in higher removal of material from the work-piece. Beyond a certain voltage, the work-piece showed a tendency towards cracking.

Effect of tool size and tool material:

Tool size:

The concept of the ECDM is that the size of the tool electrode (cathode) is much smaller than that of auxiliary electrode (anode), hence high current density at the tool electrode generates more number of hydrogen gas bubbles. Across a bubble, high potential gradient exists which develops a spark. To test this hypothesis, auxiliary electrode (anode) is made cylindrical so that the length of the anode dipped into electrolyte can be adjusted. Initially a small length of the tip of the anode is dipped into the electrolyte. But it is observed that the spark intensity at small cathode is not affected by (small) size of the anode, and cutting takes place only at the cathode. The rate of generation of hydrogen gas bubbles at cathode depends on the rate of electron transfer from cathode to the solution. Hence spark intensity at cathode (i.e. machining rate in ECDM) is not affected by the size of the anode. Machining is even possible as small size of cathode than the anode.

Tool material:

The heat conductivity of the tool-electrode affects the machining in two ways. First, it controls the heat removed from the machining zone. The heat conductivity of the tool-electrode is significantly higher than that of the electrolyte and the work-piece. Second, the heat conductivity of the tool-electrode will affect the mean temperature of the tool during machining. The higher the heat conductivity, the greater is the heat that passes through the tool-electrode, which becomes hotter for a given heat capacity of the electrode material [1].

CONCLUSION

When supply to electrolytic cell is applied in proper polarity, electrochemical action starts. Electron moves from the cathode-electrolyte interface and go the solution. At the anode electrolyte interface, equal numbers of electrons are discharged from the solution to the anode. The type of reaction depends on the characteristics of electrolyte, electrode and applied voltage. Potassium hydroxide gets reacted with silicate and water is formed.

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