International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 1 Issue 10, December- 2012

Study of Electro-Chemical Machining Process For Drilling Hole

Ripu Daman Sharma,
B.Tech. Student, CTIENT, Shahpur, Jalandhar, India

Ramandeep Singh,
Asst. Prof., MED, CTIEMT, Shahpur, Jalandhar, India

Manpreet Singh
Asst. Prof., MED, CTIEMT, Shahpur, Jalandhar, India

Abstract

Electrochemical machining is a metal machining technology based on electrolysis where the product is processed without contact and thermal influence. The metal workpiece is partially machined through electricity and chemistry i.e. electrochemical until it reaches the required end shape. The shape accuracy of the end product depends on the size of the gap. In the present study a electro-chemical machine setup was designed and fabricated to make circular hole using electrodes of different materials on workpieces of different shape and materials depending upon their oxidation potential values.

1. Introduction

Electrochemical Machining (ECM) is a non-traditional machining process belonging to electrochemical category. ECM is opposite of electrochemical or galvanic coating or deposition process. 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 the workpiece, while direct current is passed through the cell, to dissolve metal from the workpiece. The tool and the workpiece are located such that there is a gap between 0.1mm to 0.6mm between them [1,2,12,13]. On application of a potential difference between the electrodes and subsequently when adequate electrical energy is available between the tool and the workpiece, positive metal ions leave the workpiece. The tool is designed so that it is the exact inverse of the feature to be machined. ECM is widely used in machining of jobs involving intricate shapes and to machine very hard or tough materials those are difficult or impossible to machine by conventional machining. It is now routinely used for the machining of aerospace components, critical deburring, Fuel injection system components, ordnance components etc. ECM is also most suitable for manufacturing various types of dies and moulds.

2. Working Principle of ECM

When an electric current of high density and low voltage is passed through the electrolyte, the anode workpiece dissolves locally. So the final shape of the generated workpiece is approximately a negative mirror image of the tool. The electrolyte, which is generally a concentrated salt solution flows through the inter electrode gap with high velocity to intensify the mass transfer through the sub layer near anode and to remove the sludge, heat and gas bubbles generated in the gap. Machining performance in ECM is governed by the anodic behaviour of the workpiece material in a given electrolyte. When a potential difference is applied across the electrodes, several possible reactions can occur at the anode and cathode. The salt is not consumed in the electrochemical processes. Due to electrolysis the dissolution of iron from the anode, and the generation of hydrogen at the cathode occurs. No other action takes place at the electrodes [13]. The tool is advanced into the workpiece to aid in material removal [3,4,12]. A schematic of a cell used for electrochemical machining is shown in figure 1. A pump system must filter the electrolyte and circulate it because the electrolyte carries away machining waste.

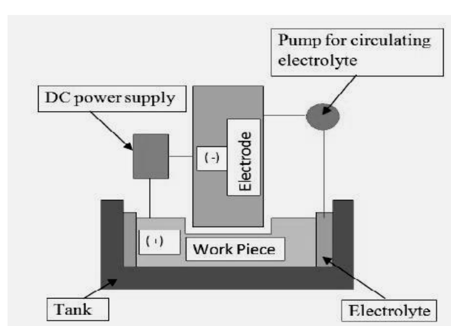

Figure 1. Scheme of ECM Process

3. Classification of ECM Process

3.1. Electrochemical Grinding Process

In the electrochemical grinding process metal is removed by electrochemical decomposition and abrasion of the metal. In this process electrode wheel revolved in the close proximity to the workpiece. Wheel is made of fine diamond particles in metal matrix. The particle is slightly projecting out from the surface and come in contact with the work surface with very little pressure. Workpiece is connected to the positive terminal and the wheel to the negative terminal. Thus current flow between the work and wheel. Wheel and its spindle are insulated from the rest of the machine. During the grinding process, a continuous stream of non corrosive salt solution is passed through work and tool and it acts both as electrolyte and coolant. This process is best suited for very precession grinding of hard metal like tungsten carbide tool tips as the grinding pressure is very less due to which the defect like grinding cracks, tempering of works, transformation of layer and dimension control difficulties are eliminated. Accuracy of the order of 0.01mm can be achieved by proper selection of wheel grit size and abrasive particles.

3.2. Electrochemical Turning Process

In this process the machine has motion of lathe and metal removal tool is a cathode which is separated from the rotating work surface (anode) by a film of electrolyte. A suitably shaped tool can produce a desired form on a hard metal in a very short time.

3.3. Electrochemical Milling Process

This is a form of etching process. In this process job is first cleaned properly. And then some sort of preventing coating is applied on the particular portion which is not to be machined. The preventive coating is of vinyl plastic. This is applied with the help of a template. Then the job is exposed to the etching material. Times depend upon the metal to be removed and the strength of chemical reagent. The metal is removed by the chemical conversion of the metal in to metallic salt. Material removal rate is mainly dependent on the selected etchant. If the metal is removed at fast rate with certain etchant then under cutting increases, surface finish decreases and more heating takes place. The etch rate is therefore limited to 0.02 to 0.04mm per minute. This process can give complicated shaped pattern on work material. But much depend upon skill of operator. It is mostly used in aircraft industry. However depth of etching is very less otherwise long time will be required and at the same time surface finish will decreases. It is mainly used for embossing, coining, engraving operation. The tooling set up cost is low. Machining is done without production of burr. And even thin sheet of metal can be processed with ease without distortion. Material which are brittle in nature can be processed with ease. This process is best suited for production of printed circuit. These circuits are produced from insulating board faced with a thin layer of copper. The copper is coated with photosensitive resist and an imagine of the required circuit is printed photographically on the surface. Etching removed all the unwanted copper. The etching vapor is very corrosive in nature and therefore, the process equipment must be kept safe from the etching and other operating equipment.

3.4. Electrochemical Wire Cutting

Electrochemical wire cutting process for removal of metal using a wire tool as cathode and workpiece as anode. The workpiece can be shaped by relative movement between it and the wire. The process is similar to wire discharge machining. This process is found to be best suited for cutting in one or two direction and fine drilling rectangular wire appears to be better choice over circular section wire. This process has a limited feed rate compared with conventional ECM. The feed rate is depending on the width of wire and the diameter of workpiece. This process is best suited super finishing with higher surface finish up to 0.15μm. This process is very suitable with small workpiece dimension. Surface finish is better for flat surface than cylindrical. The power consumption is low and tooling system is cheap. The material removal rate can be controlled precisely. The surface finish is affected by parameters like feed rate, workpiece relative speed and electrolyte flow rate.

3.5. Electrochemical Hole Drilling

Electrochemical machining can be used to machine either a single hole or a series of holes with the same characteristics. The tool is designed so that there is electrolyte flow both around and along the length of the electrode or through a hole inside the electrode so that the precipitates flow out. Flushing the precipitates is crucial in hole drilling because otherwise the removed material would pile up and form a short circuit. Most of the material is removed in the gap between the bottom of the tool and the workpiece; however the high current densities at the tip of the cathode removes some material at the sides of the cathode as the tool progresses into the workpiece. This enlarges the hole because further material leaves as the tool progresses into the workpiece. This can be overcome by coating the tool sides with an insulating material so that machining occurs only at the tool base or tip. Since the hole shape depends on the stationary cathode's shape, the holes drilled need not be round.

4. Process Parameters

The main process parameters governing the ECM process are discussed below.

4.1. Electrolyte

The electrolyte is essential for the electrolytic process to work. In addition to removing the heat generated in the cutting zone to the flow of high current, it also carries the high current and removes the product of machining. The electron movement from the cathode to the anode is dependent on the properties of the electrolyte. The electrolyte conductivity in the gap between the cathode and the anode are dependent on the following parameters: the starting electrode distance, concentration of salt in the solution, local hydroxide concentration in electrolyte, bulk and local temperature, electrolyte flow rate, and the velocity of electrolyte [7]. High flow rates of electrolyte were not desirable as they caused tool erosion. The electrolyte is pumped at about 14kg/cm2 and at speed of at least 30 m/s in order to constantly replenish the solution, which must never be allowed to reach boiling point as it would disturb the current flow. The control of electrolyte speed and flow direction are important for the machining process to continue. It is a difficult task to maintain the flow of electrolyte in the extremely small gap without affecting the tool stability [8,9]. The electrolyte should be of high electrical conductivity and be chemically active enough to cause efficient metal removal, at the same time not very corrosive. The electrolyte must have a good chemical stability.

4.2. Current and Voltage

Current density depended on the rate at which ions arrived at respective electrodes which was proportional to the applied voltage, concentration of electrolyte, gap between the electrodes, and tool feed rates. As the tool approached the work, the length of the conductive current path decreased and magnitude of current increased. This lessening of the gap and increase in current continued until the current was just sufficient to remove the metal at a rate corresponding to the rate of tool advance [11]

4.3. Electrode Gap

The gap between the tool and the workpiece must be in the range of tens of microns. The length of electrode and its position with respect to the workpiece determined the gap between the electrodes. As the gap became larger higher voltages were required to maintain the correct current density. The higher voltages resulted in wider profiles of drilled holes. If the gap was too small, the voltage dropped to a low value which resulted in narrow machined features. There was no proper electrolyte flow if the gap became low. The inter electrode gap needed to be maintained precisely as any abnormal status led to unwanted machining results [8].

4.4. Flow Rate

Although the material removal rate is dictated by the reaction rate, the flushing away of the reaction products away from the machining zone is also important for efficient machining. The selection of the ideal flow patterns and velocity was paramount for obtaining the best results. The gradient in the flow path directly affected the surface finish and depth of cut [7].

4.5. Tool Feed Rate

In ECM process gap about 0.01 to 0.07 mm is maintained between tool and workpiece. For smaller gap, the electrical resistance between the tool and work is least and the current is maximum and accordingly maximum metal is removed. The tool is feed in to the work depending upon the how fast the metal is to be removed. The movement of the tool slide is controlled by a hydraulic cylinder giving some range of feed rate [5].

4.6. Temperature Control

Since the conductivity of electrolyte varies with range in temperature, it must be held reasonably constant; otherwise the equilibrium of the machining gap will change. It may be noted that low electrolyte temperature result in low metal removal rate and high temperature leads to vaporization of the electrolyte. It is maintained around 25-60° C [6].

4.7. Tool Design

As no tool wear takes place, any good conductor is satisfactory as a tool material, but it must be designed strong enough to withstand the hydrostatic force, caused by electrolyte being forced at high speed through the gap between tool and work. The tool is made hollow for drilling holes so that electrolyte can pass along the bore in tool. Cavitations, stagnation and vortex formation in electrolyte flow must be avoided because these result a poor surface finish. It should be given such a shape that the desired shape of job is achieved for the given machining condition [5,12].

4.8. Material Removal Rate

It is a function of feed rate which dictates the current passed between the work and the tool. As the tool advances towards work, gap decreases and current increases which increases more metal at a rate corresponding to tool advance. A stable spacing between tool and work is thus established .It may be noted that high feed rate not only is productive but also produces best quality of surface finish. However feed rate is limited by removal of hydrogen gas and products of machining. Metal removal rate is lower with low voltage, low electrolyte concentration and low temperature [3,5,11].

5. Design and Fabrication of Electro-Chemical Machine

Electro-Chemical machine was designed with the objective of understanding the electrochemical hole drilling process. The design is as per figure 2.

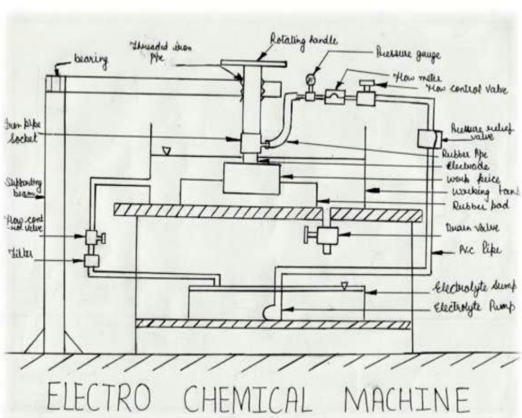

Figure 2. ECM Design

The ECM machine was fabricated with power supply of 56 Volts at 300 Ampere current. The power output is provides to the electrode and workpiece by means of copper wires of high thickness to prevent its burning by high current values. Electrode is connected with negative supply and the workpiece is connected with the positive supply.

Figure 3. ECM Machine

As per the fig. 3 the machine have two similar tanks, the upper tank acts as working tank of the machine and lower tank to act as the sump of electrolyte. The upward flow circuit of electrolyte consists of electrolyte pump which pumps the electrolyte to working tank. Next to electrolyte pump a pressure gauge is fitted in system to check the entry pressure of electrolyte in system, which is followed by pressure relief valve to relief extra pressure in system. A flow control valve to control the flow of electrolyte; flow meter to measure the electrolyte flow rate and a pressure gauge to measure outlet pressure was also used. The downward flow of electrolyte system acts under the action of gravity. However a flow control valve is fitted in system to control downward flow of electrolyte and a filter is placed in downward flow channel to filter the sludge particles formed while machining of workpiece. An overflow circuit is also fitted in the system to prevent the overflow of electrolyte in the system to prevent electrolyte loss due to overflow under any circumstances. A drain valve is provided at bottom of working tank to drain the electrolyte when system is not in use so as to prevent its concentration level and contamination from external agents. Both the tanks were insulated from the current flowing in the system for the safety of operator.

6. Experiments

Three different experiments were conducted with NaCl solution of concentration 250g/ltr as electrolyte, a current of 300Ampers at 56Volt, feed rate at 1mm/min, electrolyte flow rate at 4 ltr/min, electrolyte temperature at 30°±2° and machining time of three minutes. The different set of conditions for the experiments is as per table 1.

Table 1. The Experimental Conditions.

Expt. No.	Tool		Workpiece	
	Material	**Type**	**Material**	**Type**
1	Copper	Rod	Copper	Strip
2	Iron	Rod	Copper	Foil
3	Iron	Rod	GI	Sheet

7. Results

In first experiment it was found that the electrolyte turned black obstructing the visibility of process. For the machining time of three minutes the electrode was dissolved and a small imprint of electrode was seen on workpiece. During the second experiment a proper hole was drilled on the workpiece and electrode did not dissolve in solution. Also the electrolyte remains clear. Where as in third experiment also a proper hole was drilled in workpiece but the electrode get was dissolved in solution and the electrolyte turned black obstructing the visibility of process.

8. Conclusions

The following conclusions were drawn from the study:

- When working on same type of anode and cathode the electrode dissolve in electrolyte more rapidly than the machining of workpiece is done.
- Same type of anode and cathode change the composition of electrolyte resulting in change in its colour to black.
- Materials with higher oxidation potential remove materials from lower oxidation potential at a very fast speed.
- Electrode turns black when same material of anode and cathode were used.

References

[1]. Rajurkar, K. P., Wei, B., Schnacker, C. L., (1993). Monitoring and Control of Electrochemical Machining (ECM). Journal of Engineering for Industry, 115-217.

[2]. Rajurkar, K.P.; Zhu, D.; McGeough, J.A.; Kozak, J.; and DeSilva, A. (1999). New developments in electro-chemical machining. Annals of the CIRP, 48(2), 567-579.

[3]. Hocheng, H.; Sun, Y.H.; Lin, S.C.; and Kao, P.S. (2003). A material removal analysis of electrochemical machining using flat-end cathode. Journal of Materials Processing Technology, 140(1-3), 264-268.

[4]. Bhattacharyya, B.; Malapati, M.; and Munda, J. (2005). Experimental study on electrochemical micromachining. Journal of Materials Processing Technology, 169(3), 485-492

[5]. Hewidy, M. S., (2005) Controlling of metal removal thickness in ECM process. Journal of Materials Processing Technology, 348–353.

[6]. Jo ao Cirilo da Silva Neto, Evaldo Malaquias da Silva , Marcio Bacci da Silva, (2006). Intervening variables in electrochemical machining, Journal of Materials Processing Technology, 179, 92–96.

[7]. Stofesky, D.B. (2006). Manufacturing with microECM." Proc. of 2006 ASME Intl. Conf. on Manufacturing Science and Engineering.

[8]. Rajurkar, K.P., Levy, G., Malshe, A., Sundaram, M.M., McGeough, J., Hu, X., Resnick, R., and DeSilva, A. (2006). Micro and nano machining by electro-physical and chemical processes, Annals of the CIRP, 55(2), 643-666.

[9]. Bhattacharyya, B., Malapati, M., Munda, J., and Sarkar, A. (2007). Influence of tool vibration on machining performance in electrochemical micro-machining of copper. International Journal of Machine Tools and Manufacture, 47(2), 335-342.

[10]. Sekar T, Marappan R., (2008). Experimental investigations into the influencing parameters of electrochemical machining of AISI 202, Journal of Advanced Manufacturing Systems, 7(2), 337-43.

[11]. Mukherjee, S.K., Kumar, S., Srivastava, P.K., Kumar, Arbind, (2008). Effect of valance on material removal rate in electrochemical machining of aluminum, Journal of Materials Processing Technology, 202, 398–401.

[12]. McGeough, J. (2005). Theory of Electrochemical Machining. http://www.electrochem.cwru.edu/ed/encycl/.

[13]. Wilson, J. F., (1971). Practice and Theory of Electrochemical Machining. Wiley, New York.