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Design and Development of Electrochemical Machining Setup For C-Shaped Component

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Abstract: Electrochemical Machining (ECM) being an unconventional machining,offers a non-contact type machining in which the tool and the workpiece will not have any direct contact to each other, this capacity of ECM makes it enable to machine hard-to-hard material without any difficulty. In recent advancement of industrialization, the use hard and brittle materials like tungsten carbide, high speed steels, stainless steels etc. in intricate shapes has been increased significantly and ECM has been emerged as one of the most potential process to develop intricate shaped components. The aim of the present article is to provide the details on an in-going in-house development of apparatus of ECM for developing a simple C-shaped component. This paper will describe the details of each aspect of the ECM apparatus, material used, design of machining chamber, hydraulic system, arrangement for adjusting inter electrode gap and an expected outcome from the present apparatus

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1. INTRODUCTION

Electrochemical machining is one of the most premium choice to develop the complex shape components that cannot be done by conventional machining processes. High material removal rates are possible with electrochemical machining and that too without any thermal or mechanical stresses being transferred to the developed component. Material that used for tool has to be soft material compared to workpiece material. The principle that electrochemical machining applied is principle of electrolysis. The cathode (negative terminal) is connected to the tool and the workpiece is connected to anode (positive terminal). Both of cathode and anode are separated by a small gap known as inter electrode gap (IEG). It does not have any physical contact during the machining process (Aniket Jadhav, Kishor D. Patil, D. B. Jadhav, W. G. Kharche, 2016). In order to dissolve metal from the workpiece, the electrolyte is pumped through the gap between the tool and the workpiece, while direct current is passed through the cell (R. D. Sharma, R. Singh, M. Singh, 2012). The metal is removed by electrochemical and chemical reactions. It is in the form of sludge and precipitates (Aniket Jadhav, Kishor D. Patil, D. B. Jadhav, W. G. Kharche, 2016).Both of the tool and workpiece must be electrical conductive materials for electrochemical machining process to work. During an electrolysis process, ECM is also based on a controlled anodic electrochemical dissolution process of the workpiece with the tool in an electrolytic cell. The materials get removed (dissolved) from the workpiece based on the Faraday's law of electrolysis. Two Faraday's laws that control the electrolysis process are the amount of chemical change produced by current (the amount of any material removed) at an electrode-electrolyte boundary is proportional to the quantity of electricity used and the amounts of chemical changes produced by the same quantity of electricity in different substances are proportional to their equivalent weights.A DC Voltage is applied between tool and workpiece. 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 (R. D. Sharma, R. Singh, M. Singh, 2012). The current density is usually 15 to 200 Amperes per centimeter square (Mohan Kumar, Pramod Kumar Mahto, Divya Kushwaha, N.K. Singh, 2016). Electrolyte like copper sulfide (CuSO4) flows at high speed about 12 m/s to 65 m/s through the inter-electrode gap (IEG) that is between 0.1 mm to 0.5 mm.

2. WORKING PRINCIPLE

In this ECM process, the anode as the workpiece to be machined and the cathode of an electrolytic cell with Copper sulfate ($CuSO_4$) solution as the tool being used as an electrolyte. The tool is normally made of copper, brass, or stainless steel. The tool and the workpiece are located so there is a gap. The tool is designed so that it is the exact inverse of the feature to be machined. On application of a potential difference between the electrodes and subsequently when adequate electrical energy is available between the tool (cathode) and the workpiece (anode), positive metal ions leave the workpiece. Since electrons are removed from the workpiece, oxidation reaction occurs at the anode. The electrolyte accepts these electrons resulting in a reduction reaction (Sundarram.2008). The schematic on working of ECM is depicted in Fig. 1 and 2.

In forming hydroxides, the positive ions from the metal react with the negative ions in the electrolyte and the metal is dissolute forming a precipitate. The electrolyte is constantly transfer through the gap between the tool and the workpiece. It is to remove the unwanted machining products which otherwise would grow to create a short circuit between the electrodes. The electrolyte also carries away heat and hydrogen bubbles. The cathode is advanced into the anode to aid in material removal (Sundarram, 2008).

In this particular process, the electrolyte employed for the ECM reaction is an aqueous Copper Sulfate (CuSO4) solution. So, the tool shape remains unchanged during electrolysis. An aqueous solution of Copper Sulfate (CuSO4) using copper electrodes as active electrodes results in transfer of copper metal from the workpiece to the tool during electrolysis process. The Copper Sulfate (CuSO4) is ionized in that solution (Agashe and S. D., 2012).

CuSO4 ==> Cu 2+ + SO4 2- ....(1)

The positively charged copper ions migrate to the cathode, where each gain two electrons to become copper atoms that are deposited on the cathode.

Cu 2+ + 2e - ==> Cu ....(2)

Each copper atom loses two electrons to become copper ions at the anode, which go into solution.

Cu ==> Cu 2+ + 2e - ....(3)

The sulfate ion does not take part in that reaction and the concentration of the copper sulfate in that solution still remain. The reaction of that process is completed when the anode (workpiece) is completely eaten away. Therefore, in the electrolysis of copper sulfate, when the electrodes are weighted at the end of electrolysis, the anodic electrode will be found to have lost weight, whilst the cathodic electrode gains the weight by an amount equal to the lost by another electrode (Agashe, 2012).

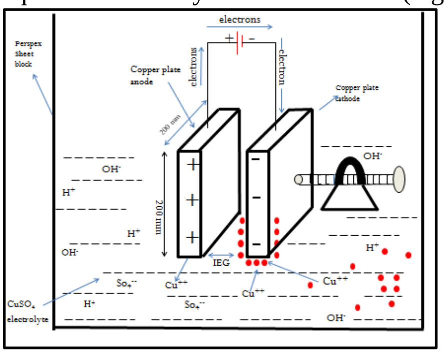

Figure 2: Electrolysis of copper sulfate solution

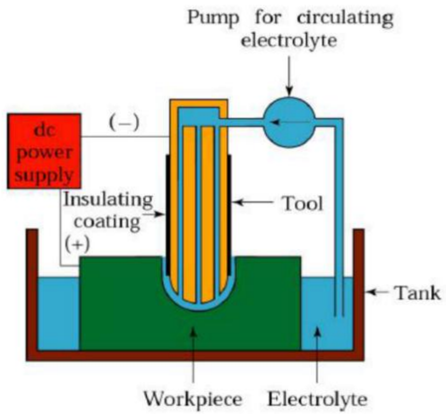

Figure 3: Schematic of ECM

3. DEVELOPMENT OF ECM APPARATUS

The machining apparatus of ECM consists of various sub components as shown in Figure 3. The sub systems are frame, machine housing, hydraulic system, electrolyte supply and recirculating system and power supply.A brief detail of the subsystems has been discussed in the sections below.

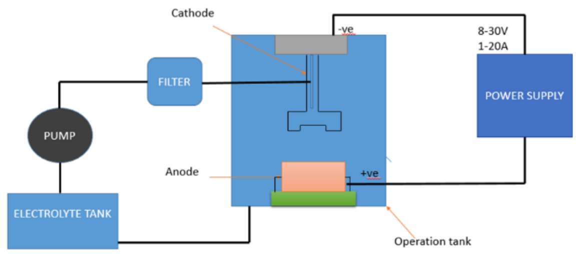

Figure 4: Schematic of ECM setup (design of cathode tool)

3.1 Machine housing

Machine housing, which is the most complicated element of the ECM machine. Itconsists of cathode tool, workpiece, housing frame, Inter-electrode gap (IEG) and tool holding.

3.1.1Cathode tool

In ECM, the cathode tool is shaped in C-shaped. The important factors to identify a cathode tool material are good electrical conductivity, easy machinability, easy availability and low cost. The most frequently used tool materials in ECM are brass and copper. In this experiment, the material that be used for the tool is copper because it is high corrosion resistance that cannot be affected by the electrolyte solution. The shaped of the tool is illustrated in the schematic diagram below.

3.1.2 Tool Holding

Tool actually holds inside the Machining Chamber. Aluminium plate whose one side is attached to movable block and at other end horizontal aluminium plate is attached. Tool is actually holds inside acrylic plate and finally acrylic plate is mount on the horizontal aluminium plate. Due to this the leakage of current is avoided.

3.1.3Housing frame

The purpose of the housing frame is to accommodate the ECM tool and work holding and positioning systems for operation as a unit. The functional requirementsinclude a suitable shape and size to provide the safe operation and maintenance and highstiffness.

3.1.4 Hydraulic system

Hydraulic system is used to control the flow rate of electrolyte in electrochemical machining. Electrolyte Storage tank stores the electrolyte solution under sufficient quantity. The centrifugal pump is used to supply the electrolyte from the tank to machining area through the pipes. The bypass connection with flow control valve is used to control the input electrolyte pressure. Pressure gauge shows the electrolyte inlet pressure. Outlet of the hydraulic system is connected to the tool inlet through the centre hole of tool it passes to machining area. Stainless steel tubing are used for the system

3.2 Electrolyte supply and cleaning system

The electrolyte, besides facilitating electrochemical functions, carries away the heat and the products of machining zone. The desirable properties of the electrolyte include: high electrical conductivity, low viscosity, high specific heat, chemical stability, resistance to formation of stiff passivating film on work surface, non-corrosiveness, non-toxic, low cost, and easy availability. The most commonly used electrolytes are sodium chloride and sodium nitrate. Most ECM machines require an electrolyte tank with storage capacity of 190 to 380 litres. Electrolyte supply and cleaning system consists of a pump, filters, piping, and control valves, heating and cooling coils, pressure and flow rate measuring devices, and storage and settling tanks. Electrolyte is pumped through a stainless steel pump to the IEG to imitate the electrolytic dissolution of the workpiece material. Filtration is usually accomplished with coarse cartridge filters made of anti-corrosive material such as stainless steel and monel. Magnetic separators or centrifugal filters can also be used. Piping and tanks are made of stainless steel, glass fibre-reinforced plastics, plastic-lined mild steel or similar other anti-corrosive materials(Pathak and Jain 2017a and 2017b).

3.3 DC power supply unit

A DC power supply unit with capability of supplying an output voltage in the range of 0–100 V, current in the range of 10-110 A and with programmable options for setting pulse-on time and pulse-off time is generally used to supply the current in the IEG. It comprises of three parts: programmable high-power DC supply, pulse generator and pulse controller with the power switch unit. A power switch apparatus is primarily assessed by switch time, control mode. The pulse controller has the facility to modify the voltage, current, pulse-on time (T_{on}), pulse-off time (T_{off}) and consequently the duty cycle (ζ) i.e. ratio of pulse-on time to sum of pulse-on and pulse-off times. Pulse phenomenon is used while using the pulsed-ECM process only (Pathak and Jain 2017).

2. Parameters related to ECM and plan for experiments

ECM and its pulsed version pulsed-ECM involves many different parameters. A typical range of different process parameters are presented in Table 1.

Parameters	Details
Type of Electrolyte	❖ Depends on the material that use. ❖ To complete electrical circuit and allow large current to pass through the gap ❖ To carry away the material removed
Electrolyte Flow Rate	❖ Sufficient electrolyte flow rate is necessary to carry away the heat and products of machining ❖ To avoid overheating of electrolyte ❖ Range : 10m/s -60 m/s
Inter-Electrode Gap (IEG)	❖ To provide constant feed towards workpiece ❖ Range : 0.1mm -0.3mm
Electrolyte Concentration	❖ To determine the electrolyte conductivity ❖ Range :> 20 g/l
Electrolyte Pressure	❖ To control the flow of the electrolyte ❖ Range : 69kPa – 2.7MPa
Voltage	❖ To supply electrical energy to the setup ❖ Range : 8 – 30 V
Current	❖ To supply current flow to the process ❖ Range : 1 -20 Amp
Electrolyte temperature	❖ Influence the oxidation potential ❖ Range : 24 – 65 °C

For the present apparatus of ECM process, the experiments planned to optimize the parameters can be divided into two stages. Firstly, pilot experiment in which three parameters; voltage, current and flow rate will be optimized to get the optimum result for these three parameters. Secondly, main experiment in which another three parameters are being tested to get the optimize result; electrolyte concentration, electrolyte pressure and inter-electrode gap (IEG). Surface roughness and geometry of the C-channel will be considered as measure for performance of the ECM process.

4.CONCLUSION

The criteria of tool geometry and various parameters and element of the electrochemical machining process (ECM) have been presented. An In-house developed apparatus of ECM for C Shaped components with a flexibility to change the cathode shape were expected to be build and from this proper design of apparatus, the optimize value of the six parameters that being considered will be provided. Besides, a higher surface finish and geometry were expected to be achieved. It was also expected that this machine will produce a higher quality of C-shaped component.

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