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FABRICATION OF ELECTRO-CHEMICAL DISCHARGE MACHINING SET-UP FOR SURFACE FINISHING

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ABSTRACT

In this project an electro-chemical discharge machining, ECDM machine is fabricated. It is basically a machine of hybrid machining process, combining the principles of electric discharge machining that is basic EDM and electro chemical machining. It is mainly used for micro machining and scribing hard and brittle, non-conductive materials. The process is basically for very small material removal, and therefore not for bulk material removing applications. So, this is a combination of two processes as the name suggests, in which one action will be by electro chemical action, and other is electrical discharge phenomena.

1 | INTRODUCTION

In this session we will discuss about another hybrid process that is ECDM, electro chemical discharge machining process. It is basically a hybrid machining process, combining the principles of electric discharge machining that is basic EDM and electro chemical machining. It is mainly used for micro machining and scribing hard and brittle, non-conductive materials. The process is basically for very small material removal, and therefore not for bulk material removing applications. So, this is a combination of two processes as the name suggests, in which one action will be by electro chemical action, which is very familiar to almost all of us in which a chemical action takes place, and that causes the dissolution of material into electrolyte called a working fluid. And therefore, the material removal from the parent body takes place.

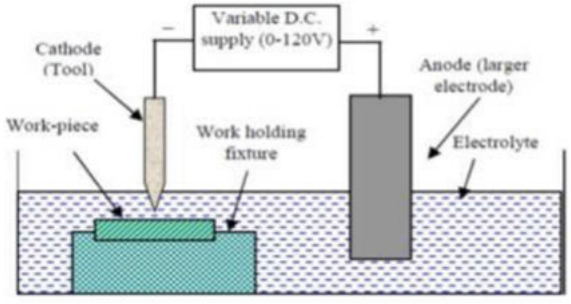

Figure 1. Overview of ECDM

In addition to that combining another phenomenon that is electrical discharge phenomena, in which we have discussed already the material removal takes place in the form of erosion due to the cavitation. And then melting and evaporation of material because of the temperatures that develops as the sparks takes place. Therefore, these two things are combined together, in this particular hybridization where basically the material removal will be done by the basic spark erosion process, which help to produce smooth surfaces. [1]

2 | OBJECTIVE OF ECDM

The objective of this report is to implement a Electrochemical Discharging Machining Model for the micro-machining and scribing hard and brittle, non-conducting, materials like glass, quartz, ceramics, etc. The setup for ECMD is shown in below Figure. 2.It is basically a hybrid machining process, combining the principles of electric discharge machining that is basic EDM and electro chemical machining. It is mainly used for micro machining and scribing hard and brittle, nonconductive materials. The process is basically for very small material removal, and therefore not for bulk material removing applications. So, this is a combination of two processes as the name suggests, in which one action will be by electro chemical action, which is very familiar to almost all of us in which a chemical action takes place, and that causes the dissolution of material into a electrolyte called a working fluid. And therefore, the material removal from the parent body takes place. In addition to that combining another phenomenon that is electrical discharge phenomena, [2]

3 | EXPERIMENTAL SETUP FOR ECDM

The experimental setup for ECDM i.e. Electrochemical Discharging machining Model is shown in Figure 2, this is working model of our project.

Figure 2. ECDM model

4 | COMPONENTS / PARTS ARE USED IN ECDM SETUP

i. Aluminium Rod

ii. Dc Motor

iii. KCL Solution

iv. Anode-Carrier

v. Cathode-Zn

vi. DC Power Supply

4.(I)| ALUMINIUM

Aluminium is a relatively soft, durable, lightweight, ductile, and malleable metal with appearance ranging from silvery to dull gray, depending on the surface roughness. It is non magnetic and does not easily ignite. A fresh film of aluminum serves as a good reflector (approximately 92%) of visible light and an excellent reflector (as much as 98%) of medium and far infrared radiation.

Figure 4. Aluminum Rod

The yield strength of pure aluminium is 7–11 MPa, while aluminium alloys have yield strengths ranging from 200 MPa to 600 MPa. Aluminium has about one-third the density and stiffness of steel. It is easily machined, cast, drawn and extruded Aluminium atoms are arranged in a face-centered cubic (fcc) structure .Aluminium is a good thermal and electrical conductor, having 59% the conductivity of copper, both thermal and electrical, while having only 30% of copper's density. Aluminium is capable of superconductivity, with a superconducting critical temperature of 1.2 Kelvin and a critical magnetic field of about 100 gauss . Aluminium is the most common material for the fabrication of superconducting qubits.[5]

4.(ii)| DC MOTOR

A DC motor is any of a class of rotary electrical machines that converts direct current electrical energy into mechanical energy. The most common types rely on the forces produced by magnetic fields. Nearly all types of DC motors have some internal mechanism ,either electromechanical or electronic, to periodically change the direction of current flow in part of the motor .DC motors were the first type widely used, since they could be powered from existing direct current lighting power distribution systems. A DC motor's speed can be controlled over a wide range, using either a variable supply voltage or by changing the strength of current in its field windings. Small DC motors are used in tools, toys, and appliances. The universal motor can operate on direct current but is a lightweight motor used for portable power tools and appliances. Larger DC motors are used in propulsion of electric vehicles, elevator and hoists, or in drives for steel rolling mills. The advent of power electronics has made replacement of DC motors with AC motors possible in many applications.[6]

Figure 5. DC Motor

4.(iii)| KCL SOLUTION

Potassium chloride (KCl) is a metal halide salt composed of potassium and chloride. It is odorless and has a white or colorless vitreous crystal appearance. The solid dissolves readily in water and its solutions have a salt-like taste. KCl is used as a fertilizer, in medicine, scientific applications, food processing, and used to cause cardiac arrest as the third drug in the "three drug cocktail" for executions by lethal injection. It occurs naturally as the mineral sylvite and in combination with sodium chloride as sylvinite. [7]

Figure 6. POTASSIUM CHLORIDE

4.(iv)| ELECTROLYTIC ANODE

An anode is an electrode through which conventional current flows into a polarized electrical device. A common mnemonic is ACID for "anode current into device". The direction of(positive) electric current is opposite to the direction of electron flow: (negatively charged)electrons flow out the anode to the outside circuit in electrochemistry, the anode is where oxidation occurs and is the positive polarity contact in an electrolytic cell. At the anode, anions (negative ions) are forced by the electrical potential to react chemically and give off electrons (oxidation) which then flow up and in to the driving circuit. Mnemonics: LEO Red Cat (Loss of Electrons is Oxidation, Reduction occurs at the Cathode), or An Ox Red Cat (Anode Oxidation, Reduction Cathode), or OILRIG (Oxidation is Loss, Reduction is Gain of electrons), or Roman Catholic and Orthodox (Reduction – Cathode, anode – Oxidation), or LEO the lion says GER (Losing electrons is Oxidation, Gaining electrons is Reduction). [8]

4.(v)| ELECTROLYTIC CATHODE-ZN

A **cathode** is the electrode from which a conventional current leaves a polarized electrical device. (This definition can be recalled by using the mnemonic *CCD* for *cathode current departs*.) A conventional current describes the direction in which positive electronic charges move. Electrons have a negative charge, so the movement of electrons is opposite to the conventional current flow. Consequently, the mnemonic cathode current departs also means that electrons flow into the device's cathode.In an electrolytic cell, the cathode is where the negative polarity is applied to drive the cell .Common results of reduction at the cathode are hydrogen gas or pure metal from metal ions .When discussing the relative reducing power of two redox agents, the couple for generating the more reducing species is said to be more "cathodic" with respect to the more easily reduced reagent. Zinc metal is used as cathode in the ECDM model. [9]

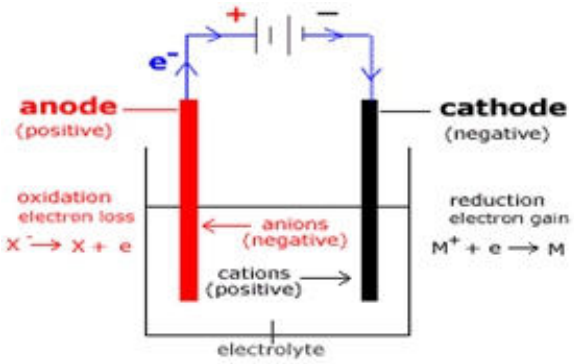

Figure 7. Cathode &Anode representation

4.(vi)| DC POWER SUPPLY

A DC power supply is one that supplies a constant DC voltage to its load. Depending on its design, a DC power supply may be powered from a DC source or from an AC source such as the power mains Schematic of basic AC-to-DC power supply, showing (from L-R) transformer, full-wave bridge rectifier, filter capacitor and resistor load Some DC power supplies use AC mains electricity

as an energy source. Such power supplies will sometimes employ a transformer to convert the input voltage to a higher or lower AC voltage. A rectifier is used to convert the transformer output voltage to a varying DC voltage, which in turn is passed through an electronic filter to convert it to an unregulated DC voltage

Figure 8. AC to DC convertor

The filter removes most, but not all of the AC voltage variations; the remaining AC voltage is known as *ripple*. DC power supply with nothing more than a transformer and a single rectifier diode, with a resistor in series with the output to limit charging current. [10]

5| WORKING PRINCIPLE OF ECDM

The working principle in ECDM is by combination of thermal and chemical mechanism. ECDM is a process in which a non-conducting material is machined by removing material through melting or vaporization by electric sparks and arcs. When a DC current is applied between the electrodes separated by a small distance (0.03 to 0.07mm) Chemical reaction takes place this causes formation of positively charged ionic gas bubbles, these bubbles forms a dielectric space around the electrodes, at an optimal voltage these gas bubbles collapses and a current of electrons generated, this results in high temperature spark, the spark erodes the material from the work piece. The material removed gets dissolved in the electrolyte. Electrolyte provides better cooling effect. Figure 1 is the schematic diagram of ECDM.

It is basically a hybrid machining process, combining the principles of electric discharge machining that is basic Electrical Discharging Machining and Electro Chemical Machining. Therefore, we have to undergo with the working principle of these two processes. [1]

6| CHEMICAL REACTION IN ECDM PROCESS

(I) CATHODE REACTION

$K^+ + e^- = K$

$K+H_20 = K(OH)+H^+$

$2H^+ +2e^- = H_2\uparrow$

It shows that there is no deposition on tool but only gas is formed, whereas, in cathode in machining an iron.

(ii) ANODE REACTION

$Iron\ (Fe) \leftrightarrow Fe^{++} + 2e^-$

$Fe^{++} + 2Cl^- \leftrightarrow FeCl_2$

$Fe^{++} + 2(OH)^- \leftrightarrow Fe(OH)$

$FeCl_2 + 2(OH)^- \leftrightarrow Fe(OH)_2 + 2Cl$

It shows that metal (work piece) i.e. Fe goes into solution and hence machined to produce reaction products as iron chloride and iron-hydroxide as a precipitate. Interesting part is that the removal is an atom by atom, resulting in higher surface finish with stress and crack free surface, and independent of the hardness of work material.[4]

7| MODES OF MATERIAL REMOVAL

Material removal mechanism in ECDM is explained by different researchers in different way.

7.(I)| THERMAL MODE:-

The first and the most acceptable mechanism of this material removal, in this ECDM process is due to the thermal mode primarily by melting and vaporization due to discharge sparking. As we have already discussed about this mechanism, which is similar to what happens in normal EDM process.

In EDM, for a particular machining condition there are numerous phenomena involved, i.e., heat conduction and radiation, phase changes, electrical forces, bubble formation and collapse, rapid solidification etc. Thermo-electric phenomenon is the most appropriate theory for the explanation of the electrical discharge machining process. The removal of material in EDM is associated with the erosive effects produced when discrete and spatial discharge occurs between the tool and workpiece electrodes. Short duration sparks are generated between these two electrodes. The generator releases electrical energy, which is responsible for melting a small quantity of material from both the electrodes. At the end of the pulse duration, a pause time begins. The forces that may be of electric, hydrodynamic and thermodynamic in nature remove the melted pools. [11]

To estimate the heat input radius due to a single spark.

$$R_{sp}=2040*(i^{0.43})*(t^{0.44})$$

Where R_{sp} is heat input radius in µm.
I is current intensity in Amp.
t is the spark time in µs.

To estimate the energy released due to a single spark.

$$E_{sp}=Vit$$

where E_{sp} = Energy released due to one spark (Watt)
I = Pulse current (Amp)
V = Gap voltage (Volt)
t = time (µs)

7.(ii)| CHEMICAL MODE:-

The other modes include chemical mode, in this chemical mode material removal is mainly through the itching process, which is seen predominantly at the green boundaries. As we know green boundaries are the locations where the densities of, densities of the atoms are much less. Therefore, for any chemical itch chance it is easier to attack these locations for any chemical reactions to take place. And in this case also these green boundaries are attacked first, in which the atomic densities are much less and therefore, the etching process starts. Some mechanical wear and spalling has also been reported in ECDM by some researchers.

8| NEED OF ECMD

The requirement of ECMD i.e. Electrochemical Discharging Machine because:

- High Accuracy and Surface Finish
- High Strength Alloys
- Complex Surface Technology Advancement
- machining on non-conducting materials[3]

9|INFLUENCING PARAMETERS

The main influencing parameter that are going to effect the ECDM process:

i. Electrolyte Concentration
ii. Voltage
iii. Gas Film
iv. Spark generation
v. Tool Electrode
vi. Auxiliary Electrode [13]

10|ADVANTAGES OF ECDM

i. No mechanical force
ii. There is no cutting forces required in ECDM.
iii. Very accurate.

iv. Relatively fast.
v. Can machine conductive & non conductive metals.
vi. No material corrosion
vii. Provides smooth surfaces
viii. Easy to work.
ix. More sensitive and repeatable.
x. Both function of ecm and edm can operate at a time .
xi. Can machining conductive as well as non-conductice materials.

11| DISADVANTAGES OF ECDM

i. More expensive than conventional machining.
ii. Need more area for installation.
iii. Electrolytes may destroy the equipment.
iv. Not environmental friendly (sludge and other waste).
v. High energy consumption.
vi. Machining upto 1.5mm only

12|APPLICATION OF ECDM

i. ECMD is novel hybrid micro-machining technology for production of:
ii. Through and blind micro-holes
iii. Micro-grooves
iv. Micro-slots Micro-channels and micro spots produced in non-conducting materials(quartz, glass, and ceramics) ect.
v. Trueing and Dressing of grinding wheels
vi. Filters for food and textiles industries
vii. Micro electro seam welding of copper plates and foils can be done by this ECDM Process
viii. The process can be effectively used for micro fabrication of an array of holes, in micro filters as we have already discussed. [13]

13|CONCLUSION

This study reveals that much has been discussed about the electrochemical discharge phenomenon and its application while machining electrically conductive and electrically non conductive materials. Since material removal in ECAM has been well explained, continuous improvement for its development is in progress and it is being effectively used to machine electrically conductive materials with higher material removal rate and improved dimensional accuracy than ECM & EDM. This discharge phenomenon has also been used to machine electrically non conductive materials and the process was named as ECDM. It was observed that ECDM had low machining efficiency due to inherent machining problems, therefore materials like glass, quartz, composites etc. those having ability to melt (at discharge temperature) were machined by this process. Researchers have also reported that ECDM could be a viable solution for machining electrically non conductive ceramics, but realizing low efficiency of the process hybrid machining especially involving abrasives or electrically conductive powder mixed electro chemical discharge machining may further improve the machining performance. This process could be used for diversified applications such as 3D micro structuring, electro chemical discharge based fused deposition for rapid prototyping, slicing / grooving of glass / quartz.

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