Elecctrochemical Machining (ECM)

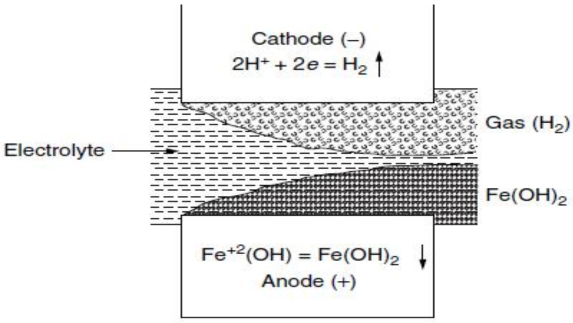
Electrochemical machining (ECM) is one of the modern and non traditional machining processes that depends on the removal of metal atoms by electrochemical dissolution (ECD) according to the Faraday principles (1833) so it is Characterized as ‘Reverse Electroplating’ becauseit removes metal instead of adding it. Gusseff introduced the first patent on ECM in 1929, and the first significant development occurred in the 1950s, when the process was used for machining high-strength and heat-resistant alloys. It is normally used for mass production and is used for working extremely hard materials or materials that are difficult to machine using conventional and old methods.

- Theory of electrochemical machining :-

ECM uses a direct current with a high density of 0.5 to 5 A/mm2 and a low
voltage of 10 to 30 V. The machining current passes through the electrolytic
solution that fills the gap between a workpiece representing the anode and a
preshaped cathodic tool. The role of the electrolyte is to flow through the interelectrode gap at high velocity, usually more than 5 m/s, to intensify the mass and charge transfer through the sublayer near the anode.
The electrolyte removes the dissolution products, such as metal hydroxides,
heat, and gas bubbles, generated in the interelectrode gap.
McGeough (1988) claimed that when a potential difference is applied across the electrodes, several possible reactions occur at the anode and the cathode. Figure 4.1 illustrates the dissolution reaction of iron in a sodium chloride (NaCl) water solution as an electrolyte. The result of electrolyte dissociation and NaCl dissolution leads to

$H_2O \rightarrow H^+ + OH^-$

$NaCl \rightarrow Na^+ + Cl^-$



The negatively charged anions OH^- and Cl^- move toward the anode, and the positively charged cations of H^+ and Na^+ are directed to the cathode.

At the anode, Fe changes to Fe^{++} by losing two electrons.

$Fe \rightarrow Fe^{++} + 2e$

At the cathode, the reaction involves the generation of hydrogen gas and the hydroxyl ions.

$2H_2O + 2e \rightarrow H_2 + 2(OH)^-$

The outcome of these electrochemical reactions is that ions of iron combine with other ones to produce as iron hydroxide, $Fe(OH)_2$.

$Fe + 2H_2O \rightarrow Fe(OH)_2 + H_2$

The ferrous hydroxide may react further with water and oxygen to form ferric hydroxide, $Fe(OH)_3$.

$4Fe(OH)_2 + 2H_2O + O_2 \rightarrow 4Fe(OH)_3$

With this metal-electrolyte combination, electrolysis has involved the dissolution of iron, from the anode, and the generation of hydrogen, at the cathode (McGeough, 1974).

<u>The process parameters :-</u>

- Power Supply

- Available in sizes up to 10,000 amp (some circuits are available up to 40,000amp)
- Range of voltage – 2 to 30 volts d.c.(A constant voltage has to be maintained and high density is required)

- Electrolyte

- Essential for electrolytic process as it cools the cutting zone which becomes hot due to the flow of high current
- Neutral salts are used as electrolyte
- Electrolyte solution is pumped the gap between the tool and the workpiece at about 2.5 N/mm2 and 30 m/s

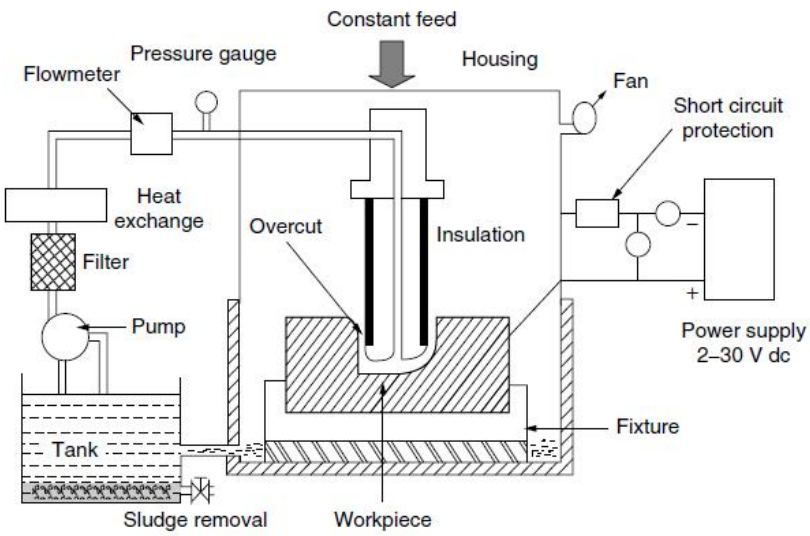
- Tool

Requirements of Tool For ECM :
- Good thermal conductivity
- Strong enough to bear high pressures
- Recommended Materials for the tool : brass, Copper or stainless steel
- Outer insulation material : Vinyl, Teflon, epoxy or high temperature varnish

- The control system

Control Parameters include Voltage, Inlet and outlet pressure of electrolyte and the temperature of electrolyte

- The current is dependent on the above factor



The process :-

- The feed control system: responsible for feeding the tool at a constant rate during equilibrium machining.
- Electrolyte supply system : supplies the electrolyte solution at a given rate, pressure, and temperature. Facilities for electrolyte filtration, temperature control, and sludge removal are also included
- Power supply unit : drives the machining current at a constant dc (continuous or pulsed) voltage.
- Workpiece holding device.

Advantages :-

- ❖ Complex components of the concave curvature can be efficiently and easily formed using concave methods.
- ❖ Same tool can be used for producing infinite number of components without being worn.
- ❖ Machining can be done at low voltages, compared to other processes, with high metal removal rates.
- ❖ Very small dimensions up to 0.05 mm can be controlled
- ❖ There is no contact between tool and work material so there are no forces and remaining stresses.
- ❖ Excellent surface finish.
- ❖ Generates less heat
- ❖ Suitable for mass production work.
- ❖ Low labor requirements.

Disadvantages :-

- Only electrically conductive materials can be machined.
- The high consumption of energy.
- It can not be used for soft material.
- The slowness of metal removal rates comparing to traditional methods
- The disability of producing sharp edges
- Difficulties occur in safely extracting and disposing of the explosive

Hydrogen gas emitted during machining processes.

- difficulties with containing the electrolyte

Applications :-

ECM has been used in many various industrial applications which range from cavity sinking to deburring. Due to the ability to machine high-strength alloys and hardened steel has led to many cost-saving applications where conventional processes are not practical.

Some of the very basic applications of electrochemical machining include:

- Die-sinking operations
- Drilling jet engine turbine blades
- Multiple hole drilling
- Machining steam Turbine blades within close limits
- Micro machining
- Profiling and contouring