ELECTRO CHEMICAL MACHINING

Principle of Electro Chemical Machining (ECM)

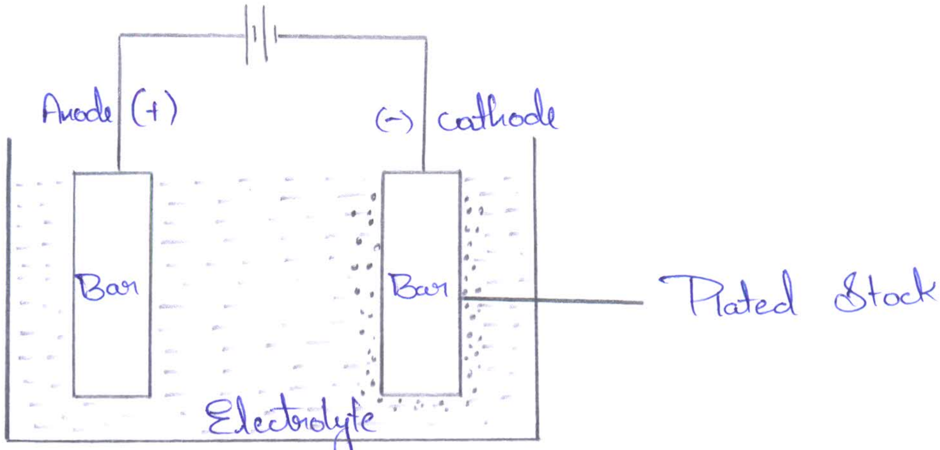


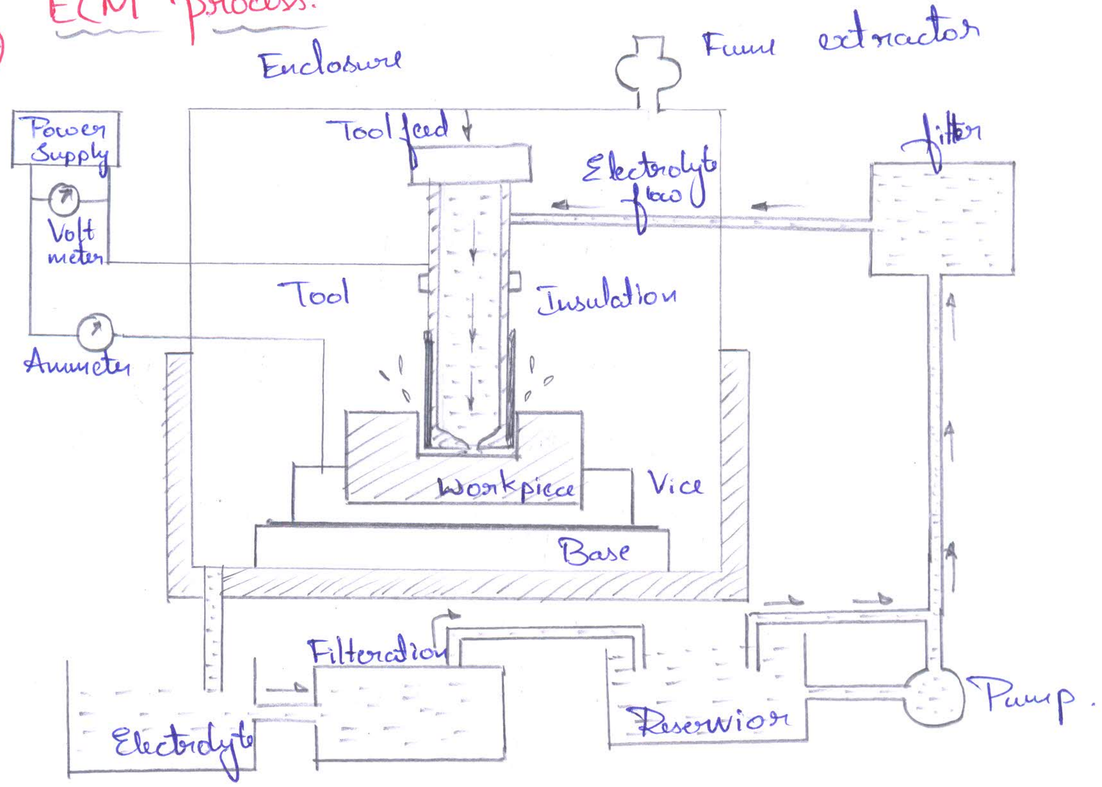
fig. Electroplating.

It works on the principle of Faraday's law of electrolysis. Two metallic bars are immersed in electrolyte. The bars are connected to positive & negative lead of the battery. When circuit is closed, direct current will pass through the electrolyte between the bars of metal. Chemical reaction in the electrolyte transfers metal in solution from the anode metallic bar and plated on the cathod metallic bar. Machining process is done by modifying and controlling the electrolytic process to produce specific shapes and dimensional limits.

In electrochemical machining process, the workpiece forms the anode, and a properly insulated tool having shape similar to that desired in the workpiece forms the cathode part of the electric circuit. The tool and the workpiece are positioned closer to each other with a conducting electrolyte flowing through a small gap between the workpiece and the tool.

When the current is passed, dissolution of the workpiece (anode) occurs. The chemical properties of the electrolytes are such that, the constituents of the workpiece material (anode) dissolve into the solution during electrolysis, but do not plate on the tool (cathode). The shape of workpiece obtained is exactly similar to the shaped tool.

Elements of ECM process.



Elements of ECM includes cathode tool, anode workpiece DC power source of sufficient capacity and electrolyte.

a) Tool:

The tool (electrode) is the negative terminal of the circuit. The tool shape must be similar to the shape of desired workpiece. To provide the gap, the size is smaller than the desired size. This difference is known as overcut. (around 0.76mm)

The material selected should be easily machinable, exhibit good stiffness to resist high electrolyte pressure, resist chemical action of the electrolyte, and a good electrical & thermal conductor.

sually Aluminium, bronze, brass, copper, stainless steel, reinforced plastics, titanium etc., are used as tool material. The insulating materials like Porcelain, vinyl, phenolic enamel, teflon and epoxy are applied by spraying or dipping to prevent machining action of tool.

b) Electrolyte:

Electrolyte performs the following functions.

- Complete the circuit between the tool and workpiece.
- Acts as conductor to carry current.
- Removes the products of electrochemical reaction from the gap between the tool and work interface.
- Carry heat generated from machining zone.

Electrolyte should possess following characteristics.

- High electrical conductivity.
- Low viscosity.
- High specific heat
- Chemical stability.
- Resistance to formation of Passivating film on work surface.
- Non corrosive & non-toxic.
- Inexpensive and easily available.

The following table shows the electrolytes that can be used for different type of materials.

SI No.	Electrolyte	Workpiece material.
1.	Sodium Chloride (NaCl) Potassium Chloride (KCl) (or) Sodium nitrate ($NaNO_3$)	Steels, iron base alloys & steels alloys with nickel and Cobalt base.
2.	Sodium Chloride (NaCl) Potassium chloride (KCl) (or) Sodium hydroxide (NaOH)	Aluminium and Aluminium alloys, copper and copper base alloys.
3.	NaCl (or) $NaNO_3$	Grey cast iron
4.	NaCl (or) KCl	Titanium alloys.

c) Filters:

Filters are placed in the system to clean the contaminated electrolyte, so that a fresh flow of electrolyte to the machining areas takes place at all times. A wire mesh filter of 75μm size made from Monel metal is commonly used. Since the filter gets clogged with small particles of grit and products of machining, they need to be cleaned once in 30 hours. Alternatively, a centrifuge separator can be used for the purpose, however, it costs more.

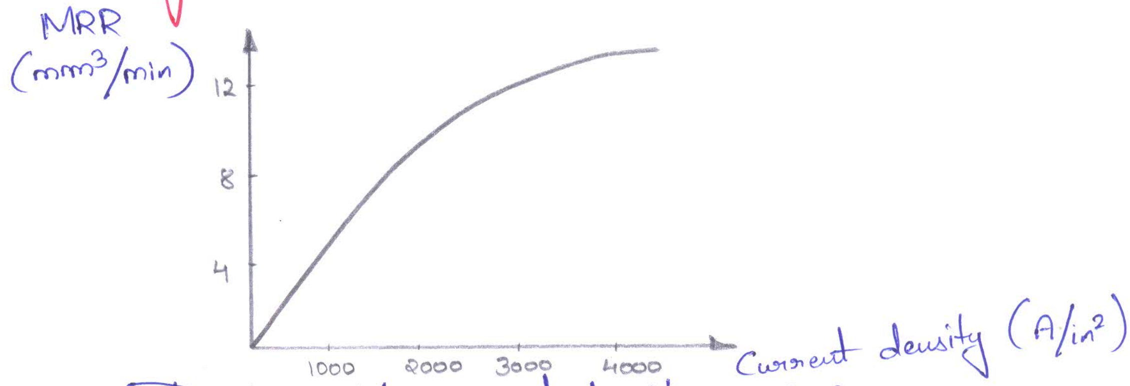
d) Power Supply:

The AC power available from the mains is converted to low voltage DC by a step-down transformer and a rectifier. Current of order 1000 - 40000A is generally required for machining, while the voltage ranges from 8-25V. It includes the protective device for switching off in the event of tool-work contact, or failure of ~~power~~ electrolyte supply, or supply of improperly filtered electrolyte.

Apart from these, ECM also consists of pumps, storage tanks, valves and pipings and others parts required for efficient machining.

Process Parameters of ECM

a) Current density:



Relation b/w current density & MRR.

Current density is simply the current that can be passed into a square inch of work area. At low current densities, metal removal rate is small. The relationship between current densities and metal removal rate is shown above. The electrochemical machine used for a particular application must have sufficient current available to maintain current density of 50 - 1500 A/in^2.

b) Tool feed Rate:

The tool feed rate is directly proportional to the current density. If the feed rate is increased, the electrical resistance of the tool work gap reduces to allow more current to flow resulting in high metal removal rates. Also surface finish and accuracy is improved.

c) Gap between workpiece and tool:

The tool and the workpiece are positioned as close together to encourage efficient electrical transmission. Small gap results in high current densities and hence, more metal removal rate. The gap size may vary from 0.25 - 0.75mm. A gap size of 0.25mm is often used.

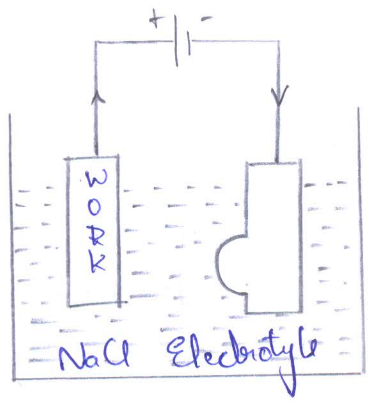
d) Velocity of Electrolyte flow:

Electrolyte flow may be between 15-60m/s. If electrolyte flow is too slow, the heat and by-products of electrolytic reaction build in the gap causing non-uniform metal removal. Too high velocity will cause cavitation, also promoting non-uniform metal removal.

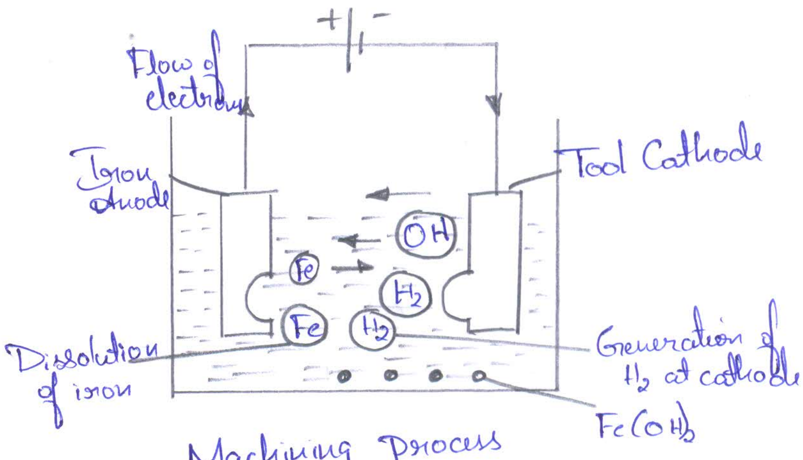
e) Type of Electrolyte, its concentration and temperature.

The type of electrolyte selected depends upon the tool and workpiece material. The electrolyte in water at various concentrations affect the surface finish produced. The power loss in electrolytic reaction gives rise to an increase in temperature of electrolyte. Low temperature of electrolyte is conducive to better surface finish and tolerances.

CHEMISTRY OF ECM



Tool- work arrangement



Machining process

The above fig. shows the chemical reaction in ECM of low carbon steel with NaCl solution as electrolyte. With suitable potential, the electrolyte undergoes ionic dissociation

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

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

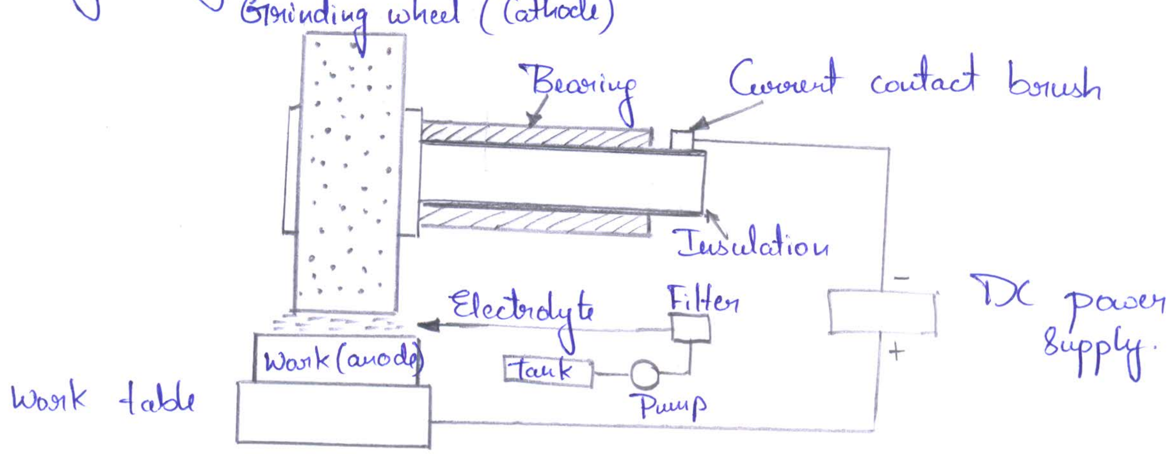
As the potential difference is applied between work & tool, the Fe^{++} ions from work moves towards cathode tool, reacts with OH^- that have been attracted to the anode workpiece to form ferrous (or) iron hydroxide $Fe(OH)_2$.

$$Fe + 2H_2O \longrightarrow Fe(OH)_2 + H_2.$$

Also within the electrolyte, iron ions would combine with chloride ions to form $FeCl_2$. Both $FeCl_2$ & $Fe(OH)_2$ gets precipitated in form of sludge. The flow of electrolyte removes metal from workpiece & the tool is advanced at same rate as metal removal. Since H_2 gas only is liberated, this will not affect the shape of the worksurface.

Electro Chemical Grinding:

Electrochemical grinding, also called as electrolytic grinding is a variation process of electrochemical machining (ECM). The process makes use of a grinding wheel embedded with insulating abrasive particles such as Al_2O_3 (or) diamond, set in a conducting bonding material. The electrolyte sodium nitrate in water is supplied through nozzle for machining process. Contact wire brushes are used on the spindle of the grinder to supply current into the spindle from which it then flows to the grinding wheel.

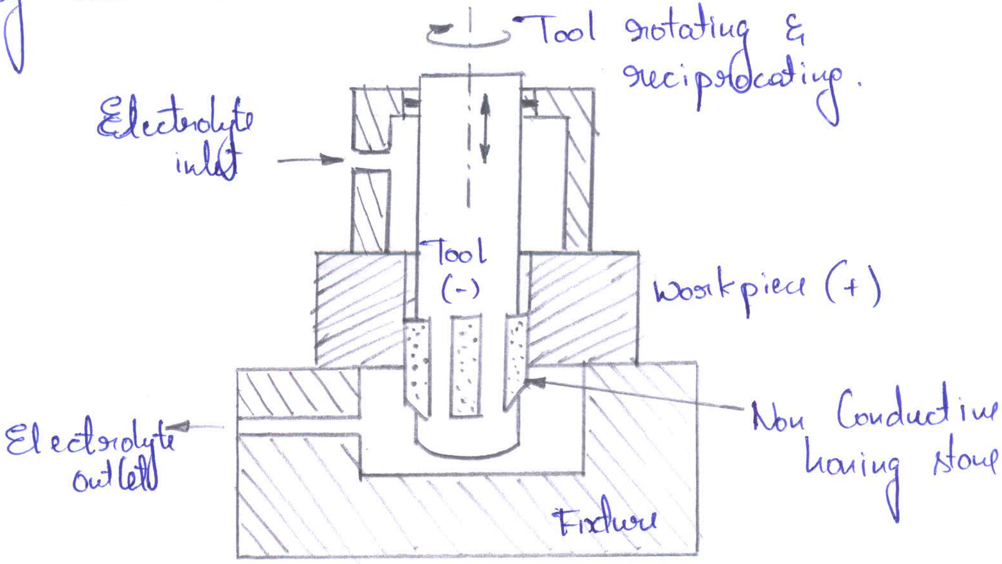


ECG Process.

When a DC voltage of about 5-15V is supplied between the work and tool, with suitable current density, material is removed from work surface by electrochemical & abrasive action of grinding wheel. 10% volume is removed by abrasive action while 90% by electro chemical action. The workpiece material goes into solution as metal ion and bubbles of H_2 are generated at the wheel.

Electrochemical honing (ECH):

Electrochemical honing is a modification of conventional honing, wherein material from the electrically conducting workpiece is removed by the electrochemical and abrasive action.



ECH process

The hollow stainless steel tool is rotated and reciprocated on a rigid spindle for precise metal removal from hole of workpiece. Around 3 bonded abrasive stones of length half of length of bore. The bores are nonconductive and assist electrochemical action.

During the beginning, the honing stones are made to protrude by a small distance about 0.2mm to create gap for electrolyte flow. Suitable electrolyte such as NaCl (or) $NaNO_3$ is supplied under pressure. The material is removed when the tool rotates and reciprocates by combined action of electrochemical & abrasive materials. As material is removed, the stone expands to maintain constant contact against the work surface, the process continuous until the required finish is obtained.