ATME College of Engineering

Introduction to Non-Traditional Machining BME405A

Electrochemical Machining (ECM)

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Module - 3

ELECTROCHEMICAL MACHINING (ECM)

- Introduction, Principle of electro chemical machining: ECM equipment, elements of ECM operation, Chemistry of ECM.
- Process parameters: Current density, Tool feed rate, Gap between tool & work piece, velocity of electrolyte flow, type of electrolyte, its concentration temperature, and choice of electrolytes.
- ECM Process characteristics: Material removal rate, accuracy, surface finish.
- ECM Tooling: ECM tooling technique & example, Tool & insulation materials.
- Applications ECM: Electrochemical grinding and electrochemical honing process. Advantages, disadvantages and application of ECG, ECH.

CHEMICAL MACHINING (CHM)

- Elements of the process: Resists (maskants), Etchants.
- Types of chemical machining process-chemical blanking process, chemical milling process.
- Process characteristics of CHM: material removal rate, accuracy, surface finish,
- Advantages, limitations and applications of chemical machining process.

Introduction to Electrochemical machining

- Electrochemical Machining (ECM) is one of the newest and most useful non-traditional machining (NTM) process belonging to Electrochemical category.
- Electrochemical machining (ECM) is used to remove metal and alloys which are difficult or impossible to machine by mechanical machining process.
- Electrochemical Machining (ECM) works on the principle of reverse electroplating.
- This machining process is based Michael Faraday's classical laws of electrolysis, requiring basically two electrodes, an electrolyte, a gap and a source of D.C power of sufficient capacity.

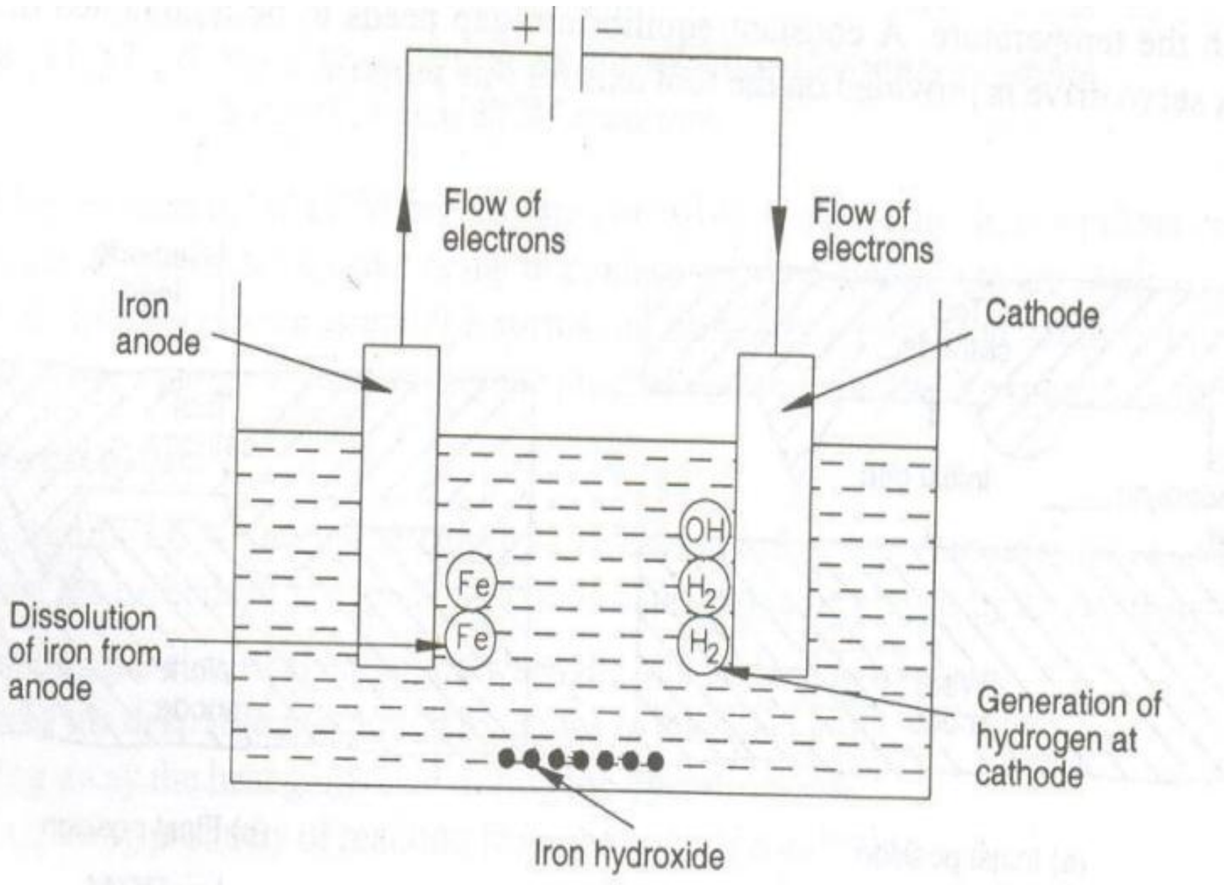
Electrochemical machining

Electrical energy used in combination with chemical reactions to remove material

• Relies on the principle of electrolysis for material removal

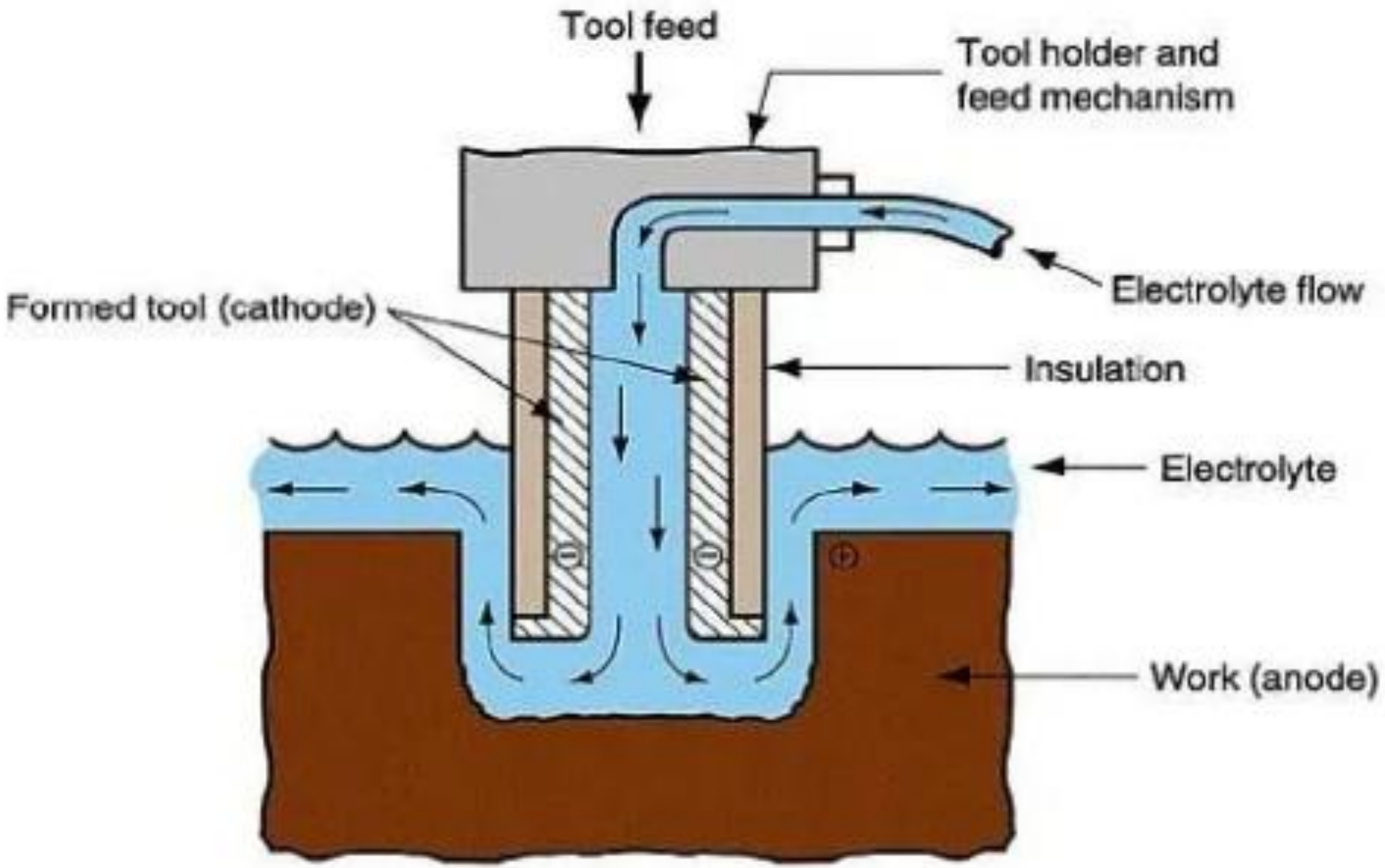
• Michael Faraday discovered that if two electrodes are placed in a bath containing a conducting liquid and a DC potential is applied across them, then metal can be depleted from the anode and plated on the cathode –process universally used in electroplating by making the workpiece the cathode

• In ECM, the material is removed and hence electroplating is reveresed, i.e. workpiece is made the anode. Hence, the Work material must be a conductor.



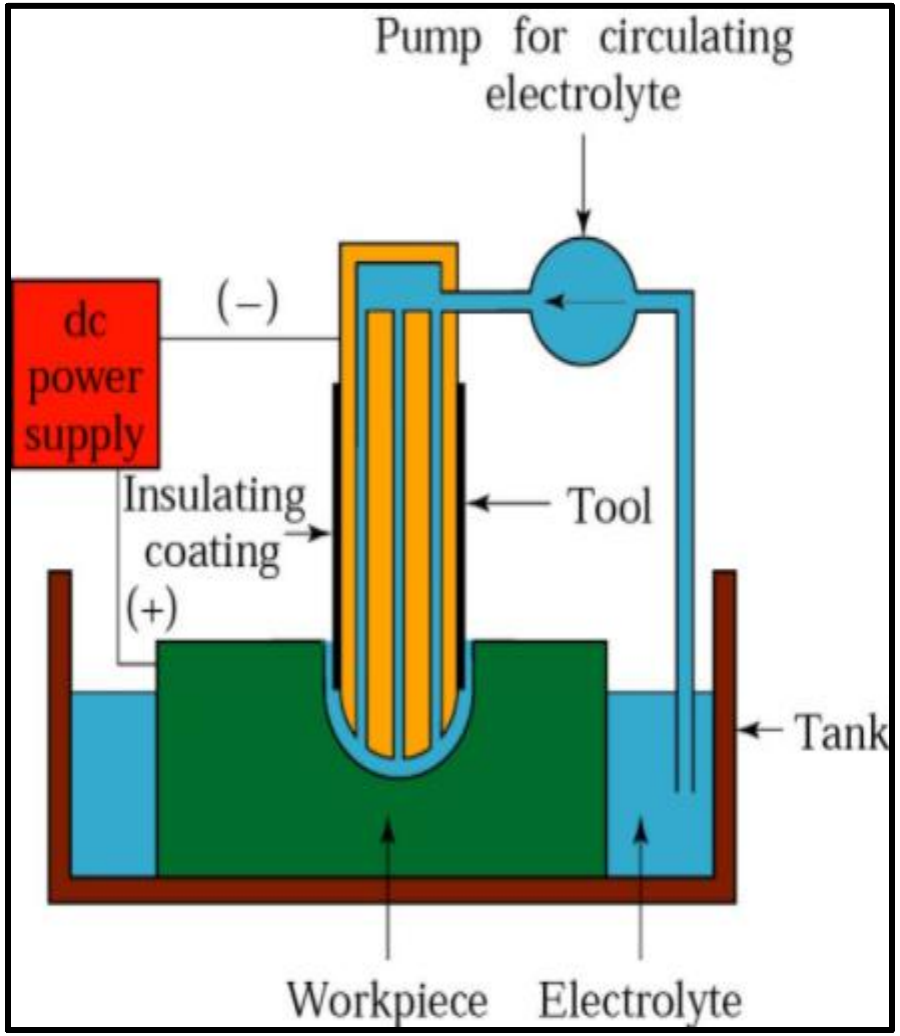
Principle of electrolysis

Electrochemical machining



Introduction to Electrochemical machining

- In the actual process of ECM, the cathode is tool shaped(mirror image of work-piece) and anode is the work-piece.
- A gap(0.05 to 0.7 mm) is provided between the tool and work-piece and electrolyte flows through the gap at a velocity of 30 to 60 m/s and it completes the electrical circuit.
- Electrolyte is pumped at high pressure of 20 kgf/cm^2(1.96 MPa) through the gap.
- Electrolyte must be circulated at a rate sufficiently high to conduct current between them and to carry heat.
- Metal is removed from the work-piece by dissolution.



Elements of ECM process

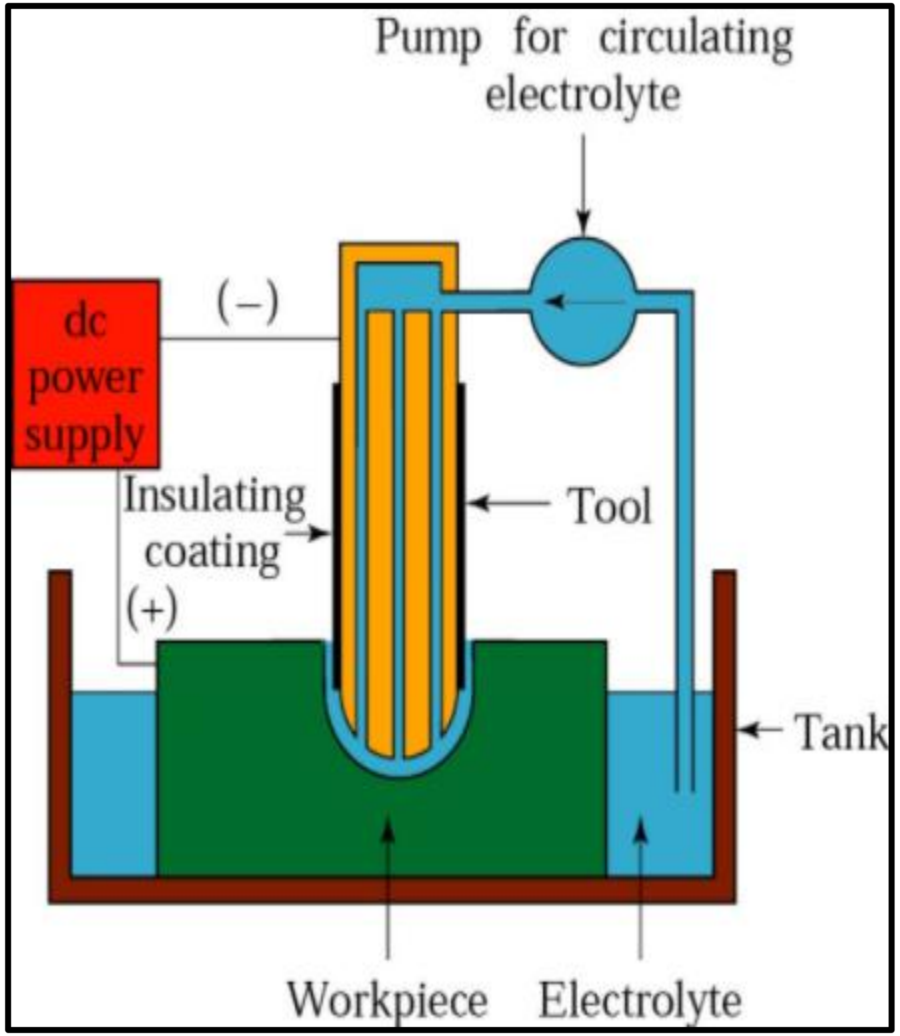
The elements of ECM process include:

a. Cathode tool, having shape similar to that desired in the workpiece metal.

b. Anode workpiece, which is a good conductor of electricity.

c. DC power source of sufficient capacity so that high current densities can be maintained between the tool and the workpiece,

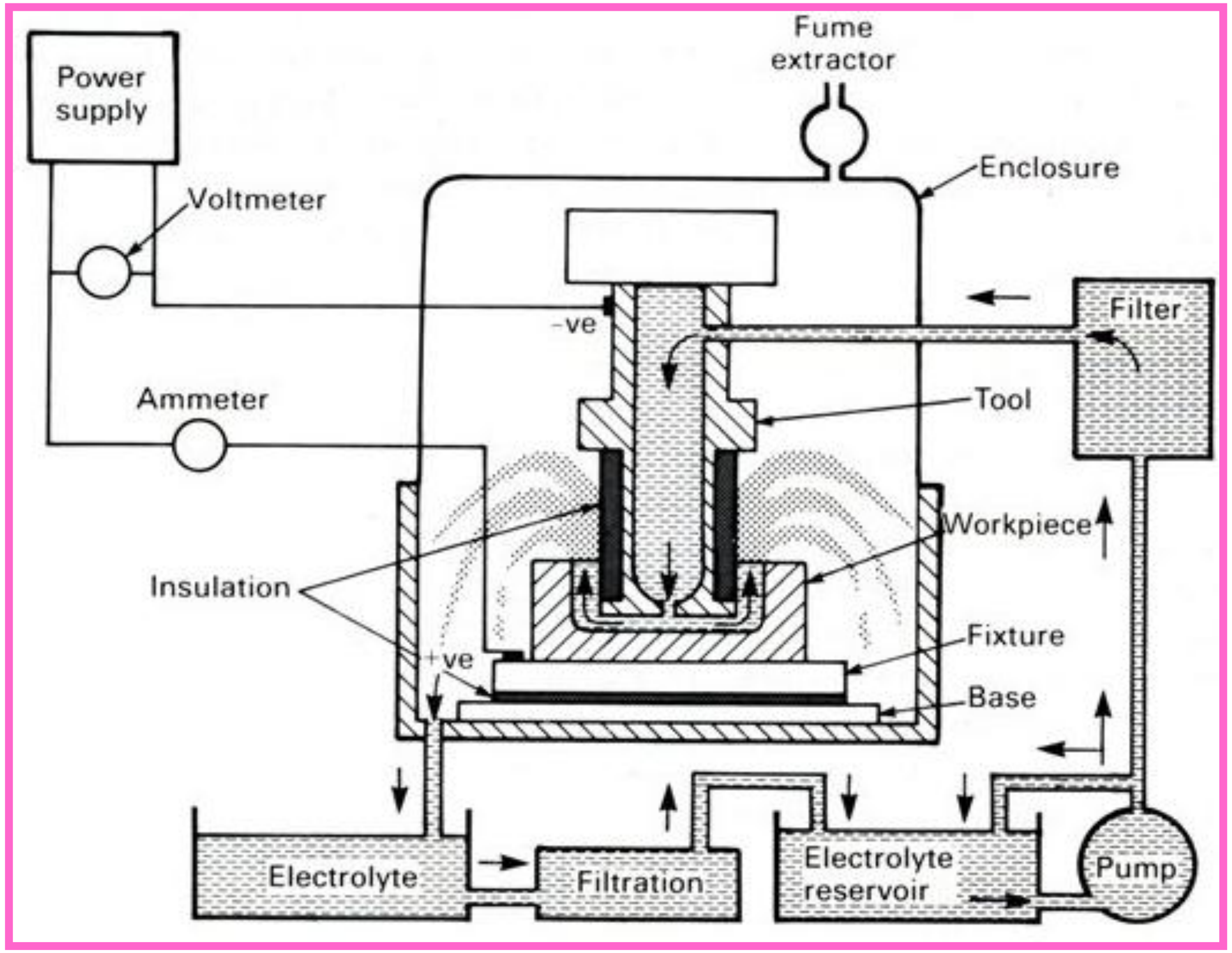
d. Electrolyte, a liquid that carries electric current and also acts to complete the circuit between the tool and the workpiece metal



Equipment of Electrochemical Machining

The equipment mainly consists of the following parts:

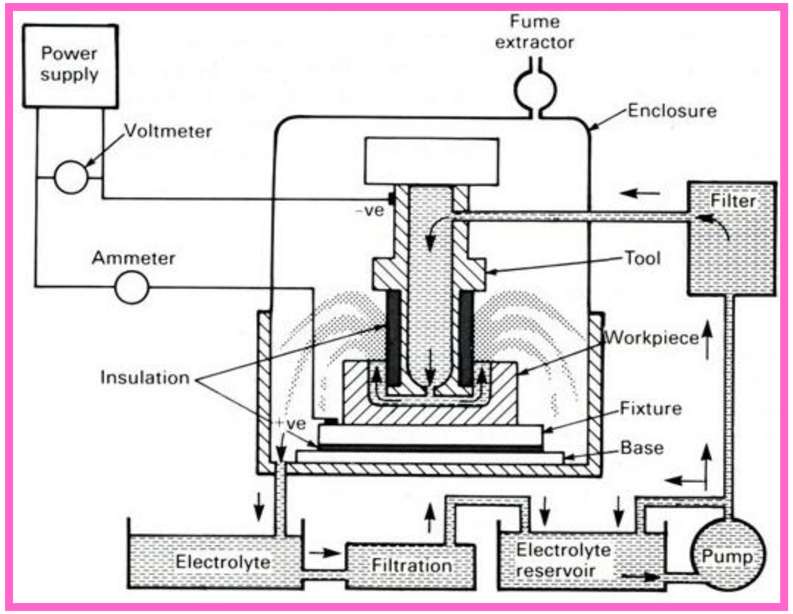
1. Tool
2. Electrolyte
3. Filters
4. Source for Power supply



Equipment of Electrochemical Machining

1. Tool

- The tool, also called electrode forms the negative terminal (cathode) of the electric circuit. The shape of the tool must be similar to the shape desired in the workpiece.
- The material selected for the tool should be easily machinable, exhibit good stiffness to resist high electrolyte pressures, resist chemical action of the electrolyte, and a good electrical and thermal conductor.
- Usually aluminum, bronze, brass, copper, stainless steel, titanium etc., are used as tool materials.



Equipment of Electrochemical Machining

2. Electrolyte

In electrochemical machining, the electrolyte performs the following functions

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

Equipment of Electrochemical Machining

2. Electrolyte

Sodium chloride, Potassium chloride, Sodium nitrate & Sodium chlorate are some of the inorganic salts used as electrolyte in ECM.

The electrolyte should possess the following characteristics:

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

Equipment of Electrochemical Machining

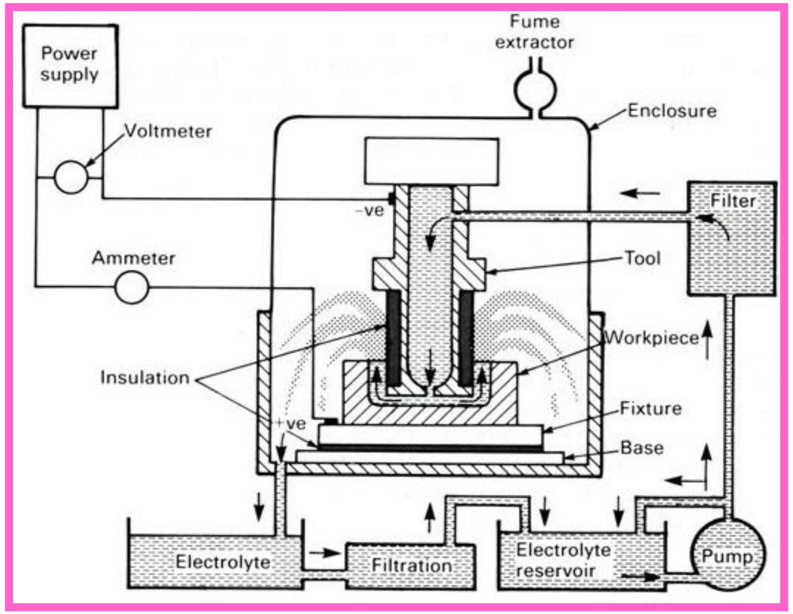
2. Electrolyte

Sl. No.	Electrolyte	Workpiece material
1	Sodium chloride (*NaCl*). Potassium chloride (*KCl*) and Sodium nitrate ($NaNO_3$).	Steels, iron base alloys and or steel alloys with nickel and cobalt base.
2	Sodium chloride (*NaCl*). Potassium chloride (*KCl*) or Sodium hydroxide (*NaOH*).	Aluminum and aluminum alloys, copper and copper base alloys.
3	Sodium chloride (*NaCl*). Potassium chloride (*KCl*) and Sodium nitrate ($NaNO_3$).	Gray cast iron
4	Sodium chloride (*NaCl*). Potassium chloride (*KCl*)	Titanium alloys.

Equipment of Electrochemical Machining

3. Filters

- Filters are placed in the system to clean the contaminated electrolyte, so that a fresh flow of electrolyte to the machining area takes place at all times.
- A wire mesh filter of 75 um size made from Monel metal is commonly used.
- Since the filters get clogged with small particles of grit and products of machining, they need to be cleaned once in 30 hours.

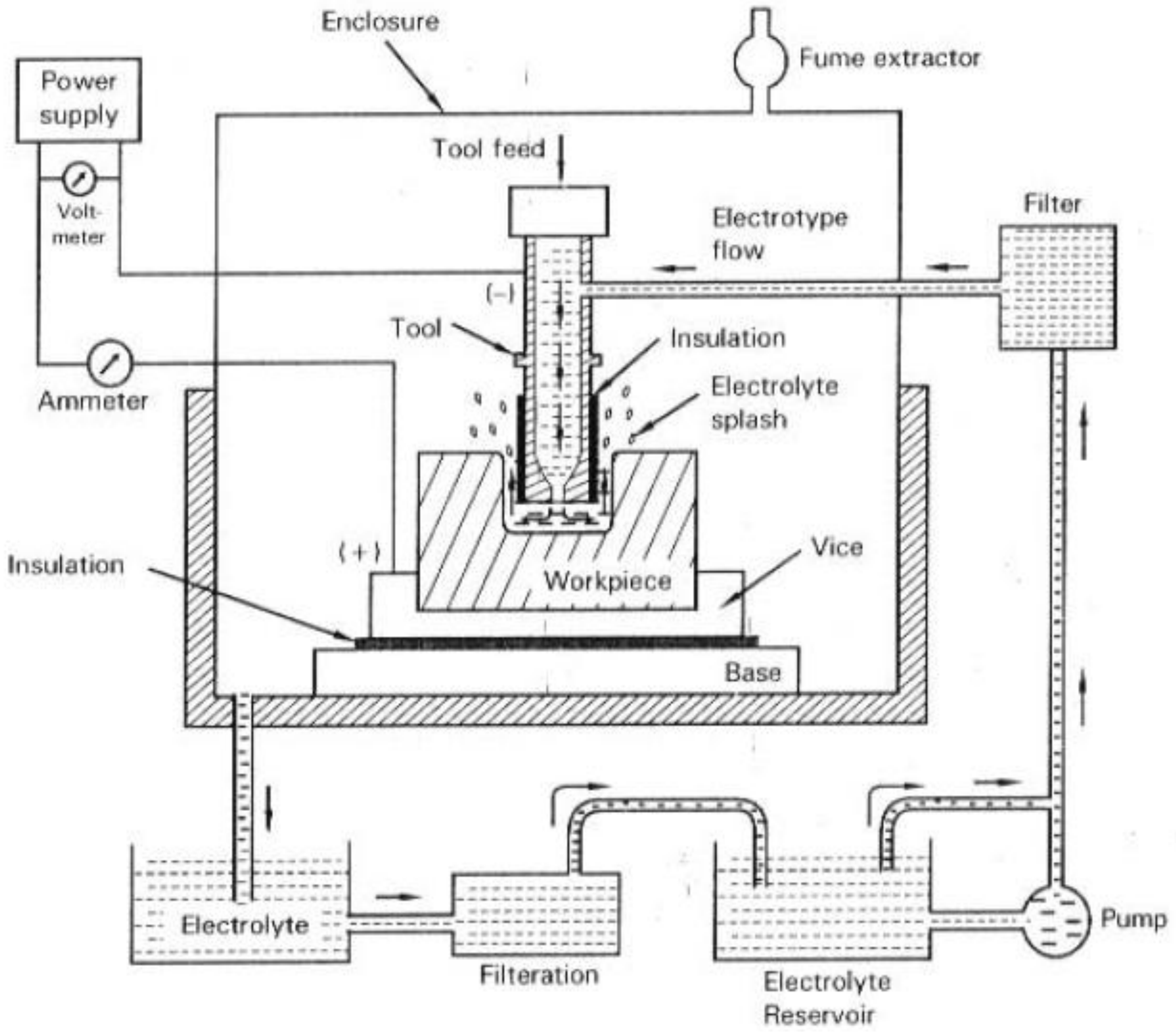


4. Source for Power supply

- The AC power available from the mains is converted to low voltage DC by a step-down transformer and a rectifier.
- Current of the order of 1000-40,000 A is generally required for machining, while the voltage ranges from 2 - 25 V.
- The power supply also includes a protective device for switching OFF in the event of the tool getting too close to the workpiece, or failure of electrolyte supply, or supply of improperly filtered electrolyte.
- Apart from the above parts, ECM equipment consists of pumps, storage tank, valves and piping, special drive systems that ensure slow and accurate movement of the took and other parts required for efficient machining.

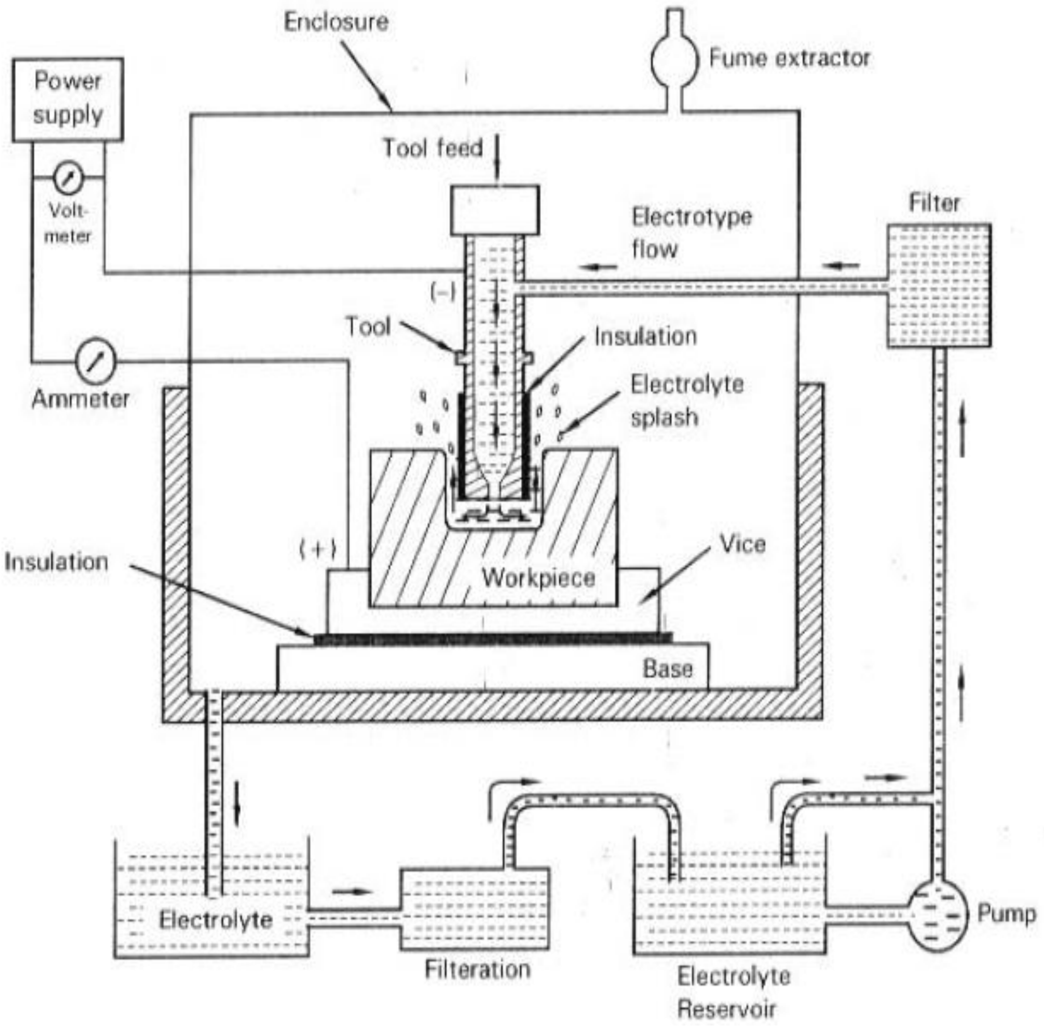
ECM OPERATION

- In operation, the tool having a shape, similar to that desired in the workpiece is fed towards the workpiece maintaining a small gap of approximately 0.25 mm between them.
- A high-current, low-voltage DC power supply is connected between the tool and the workpiece, The tool is connected to the negative terminal (cathode) and the workpiece to the positive terminal (anode).



ECM OPERATION

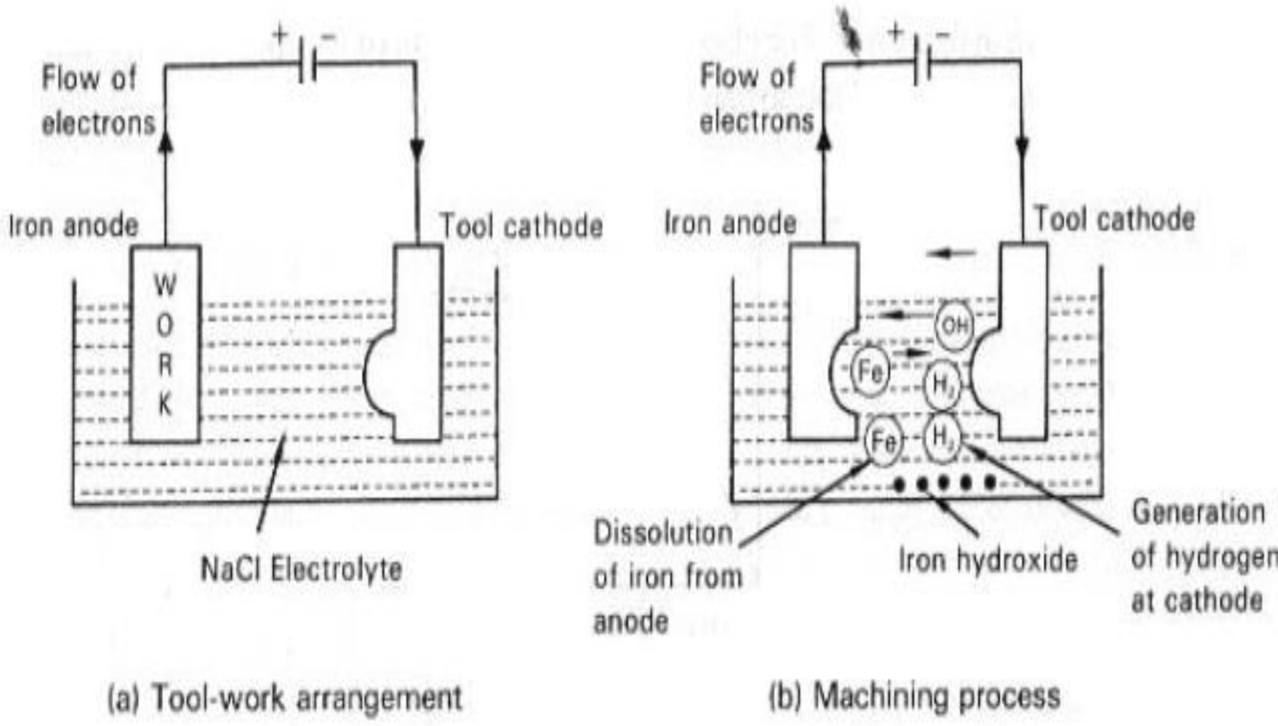
- The electrolyte is pumped at a high-pressure through the Small gap between the tool and the workpiece, thus providing the necessary path for electrolysis.
- When the current is passed, dissolution of the workpiece (anode) occurs. Meanwhile, the flowing electrolyte washes the metal ions away from the workpiece before they have a chance to plate onto the tool.
- As the tool moves downwards to maintain a constant gap, the workpiece is machined to the same shape as that of the tool.



Chemistry of ECM Process

- The chemical reactions in electrochemical machining of a low carbon steel workpiece (containing iron as chief constituent) with sodium chloride (NaCl) solution in water as electrolyte is represented by the figure
- When a suitable potential difference is applied, the electrolyte undergoes ionic dissociation as shown below.

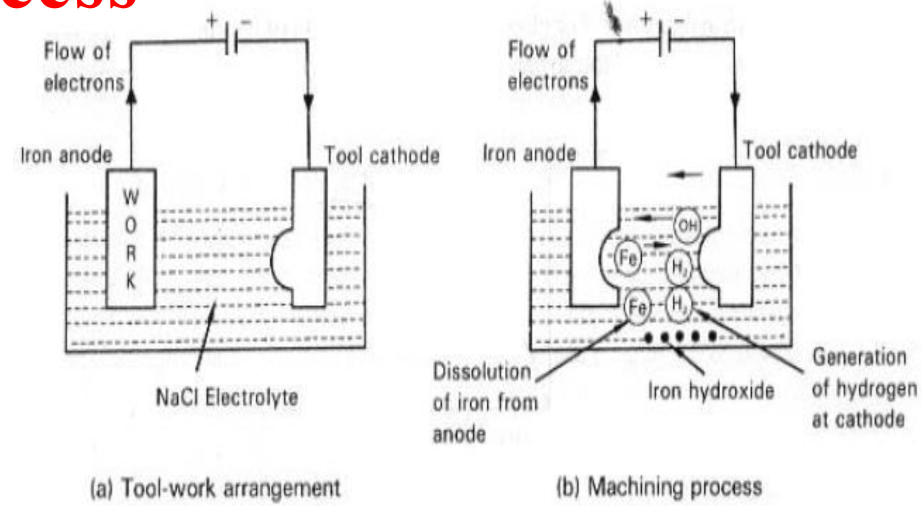
$$NaCl \rightarrow Na^{+} + Cl^{-}$$
$$H_2O \rightarrow H^{+} + OH^{-}$$



Chemical reaction in ECM

Chemistry of ECM Process

- As the potential difference is applied between the workpiece (anode) and the tool (cathode), the positive ions (Fe++) from the workpiece, move towards the cathode tool, reacts with the negative hydroxyl ions (OH-) that have been attracted to the anode workpiece to form ferrous or iron hydroxide Fe(OH)



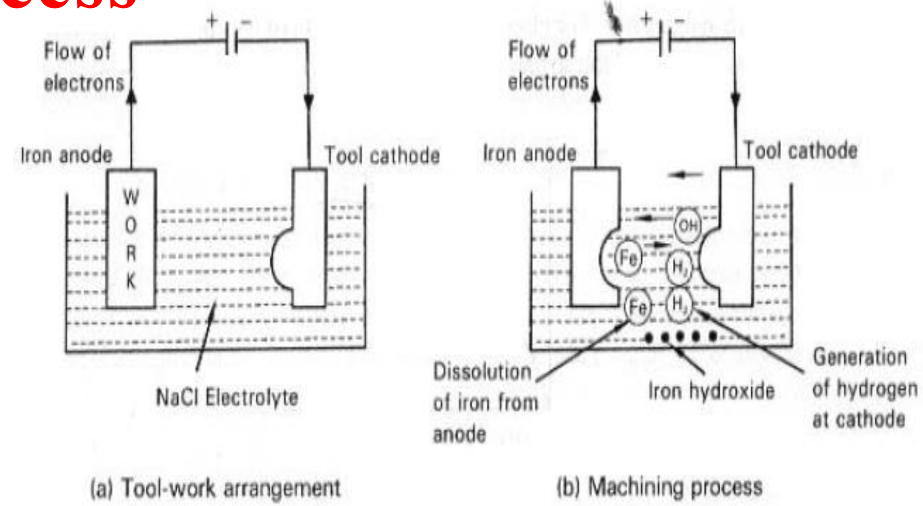
Chemical reaction in ECM

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

- Also, within the electrolyte, iron ions would combine with chloride ions to form iron chloride (FeC2). Both FeCl, and Fe (OH), get precipitated in the form of sludge. The process continues and in this manner the workpiece gets gradually machined and gets precipitated as sludge.

Chemistry of ECM Process

- The flowing electrolyte carries away the products of machining.
- As machining takes place, the cathode tool is advanced towards the anode workpiece at the same rate at which the material is removed. The cathode tool reproduces its shape in the anode workpiece.
- It is important to note that only hydrogen gas is evolved at the cathode tool and hence the shape of the tool remains unaltered during the machining process.



Chemical reaction in ECM

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

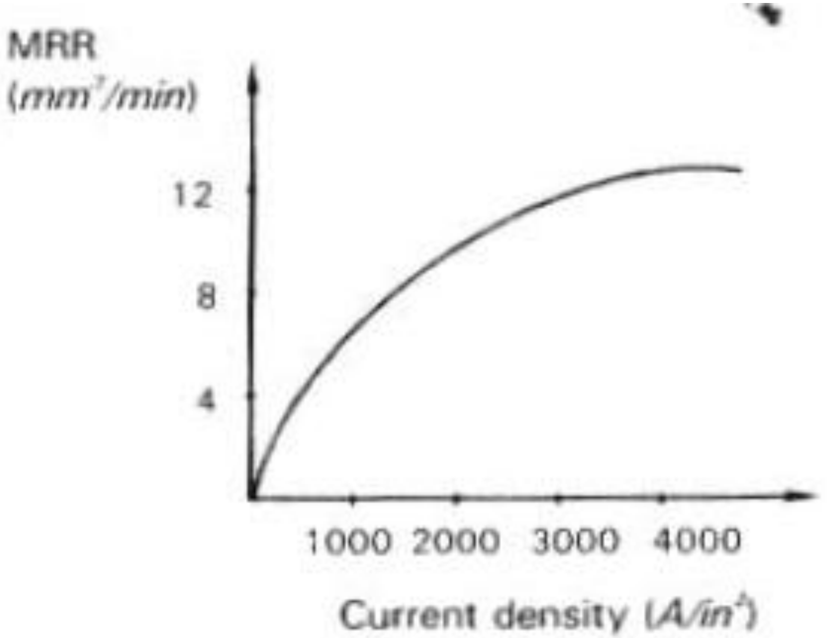
Process Parameters of ECM (variables)

1. Current Density
2. Tool Feed Rate
3. Gap between Tool and Workpiece
4. Velocity of Electrolyte Flow
5. Type of Electrolyte, its Concentration and Temperature

Process Parameters of ECM (variables)

1. Current Density

- 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 density & metal removal rate is shown in figure
- The electrochemical machine used for a particular application must have sufficient current available to maintain a current density of 50 - 1500 A/in^2.



Relation between current density and MRR

Process Parameters of ECM (variables)

2. Tool Feed Rate

- The tool feed rate is directly proportional to 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.

Process Parameters of ECM (variables)

3. Gap between Tool and Workpiece

- 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 0.76 mm. A gap size of 0.25 mm is often used.
- It is important to maintain a uniform gap between the tool and the workpiece. Any physical contact of the tool and the workpiece results in arcing and serious damage to both the members.

Process Parameters of ECM (variables)

4. Velocity of Electrolyte Flow

- Electrolyte flow may be between 15 - 60 m/sec.
- If electrolyte flow is too low, the heat and by products of the electrolytic reaction (hydrogen gas bubbles, sludge etc.) build in the gap causing non-uniform metal removal
- Too high velocity will cause cavitation, also promoting non-uniform metal removal.

Process Parameters of ECM (variables)

5. Type of Electrolyte, its Concentration and Temperature

- The type of electrolyte selected depends on the tool and the workpiece material.
- For instance, **sodium chloride** is cheap and possesses good conductivity. However, it is corrosive and hence, cannot be used on tungsten carbide or molybdenum materials.
- **Sodium nitrate** is also popular due to is less corrosive nature. But, it does not produce a good surface finish as that of sodium chloride. Also, it is more expensive than sodium chloride. It is preferred for machining aluminium and copper.

Process Parameters of ECM (variables)

5. Type of Electrolyte, its Concentration and Temperature

- The electrolyte in water at various concentrations affect the surface finish produced
- Low concentrations decrease the equilibrium machining gap resulting in better surface finish and tolerance control.
- Electrolyte temperature seriously affects overcut. The power loss in the electrolytic reaction gives rise to an increase in the temperature of the electrolyte.
- The heat must be carried away from the cutting area so as to maintain stable and steady conditions.
- Low temperature of electrolyte is conductive to better surface finish and tolerances.

ADVANTAGES of ECM

a. Accurate shape with good surface finish can be obtained.

b. Machined surface is stress-free and has high surface finish.

c. No physical contact between the tool and the workpiece. Hence, no tool wear, and also no burrs are produced

d. Capable of machining metals and alloys irrespective of their strength and hardness.

e. Metal removal is due to anodic (workpiece) dissolution. Hence, no thermal effects on the workpiece.

f. Process can be easily automated.

g. Several tools could be connected to a cassette to make many cavities simultaneously

h. Suitable for mass production applications.

LIMITATIONS of ECM

a. Suitable only for conductive materials.

b. Inability to machine sharp interior edges and corner because of very high current densities at these points

c. Space and floor requirements are higher than conventional machines.

d. High electrical power is consumed.

e. Post-machining and cleaning is a must to reduce the corrosion of workpieces.

f. Limited to mass production because of high tooling and set-up costs.

g. Not environmental friendly. The sludge produced in large amounts need to be disposed off.

h. Frequent maintenance of equipment is necessary in order to avoid corrosion of parts.

APPLICATIONS of ECM

a. The most common application of ECM is high accuracy duplication. Because there is no tool wear, it can be used repeatedly with a high degree of accuracy.

b. It is commonly used on thin walled, easily deformable and brittle material because they would probably develop cracks with conventional machining.

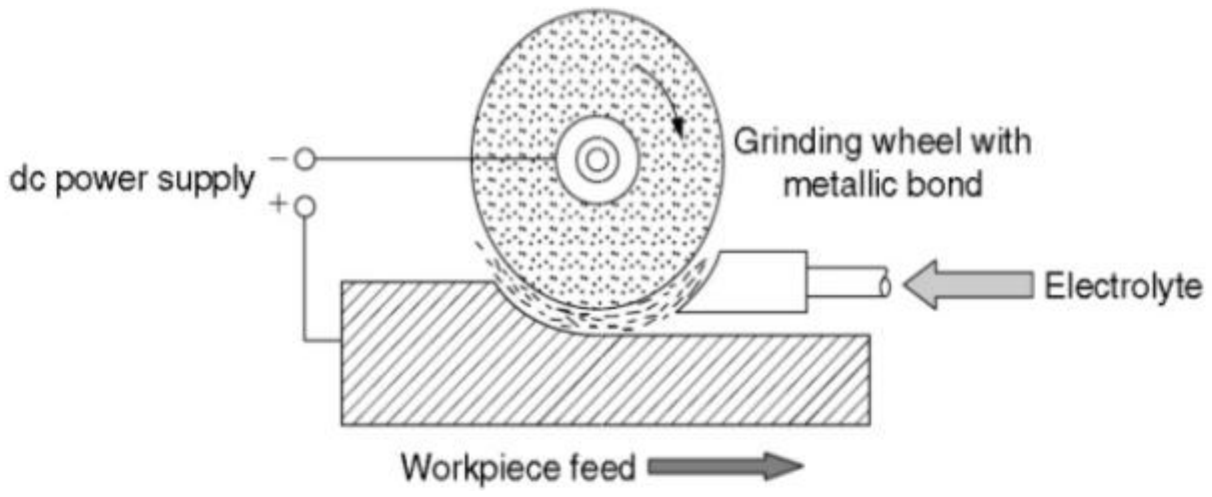
c. It is used in machining of hard-heat-resisting alloys.

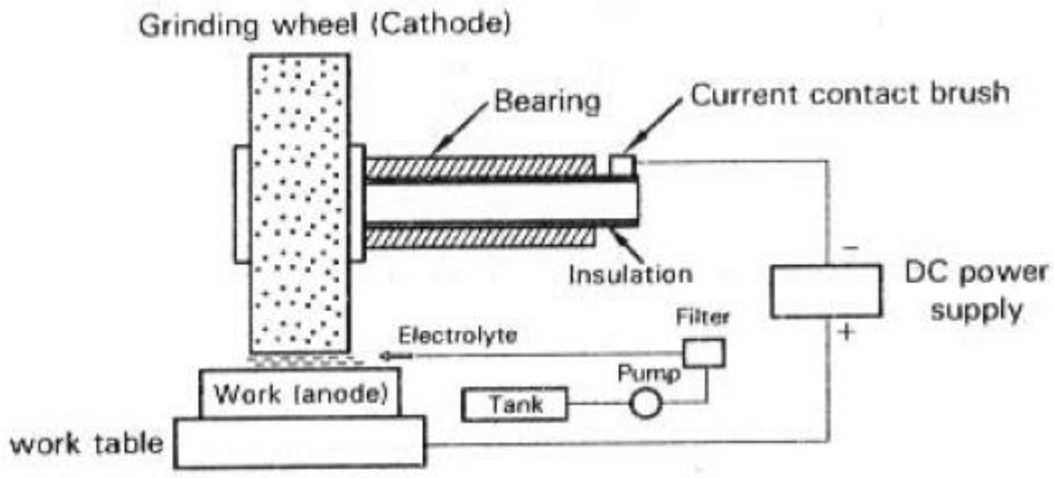
d. It is used in cutting cavities and holes in various products, machining of complex external shapes like that of turbine blades, aerospace components and machining of tungsten carbide and nozzles of alloy steels.

e. Any conducting material can be machined by this method.

Electrochemical Grinding

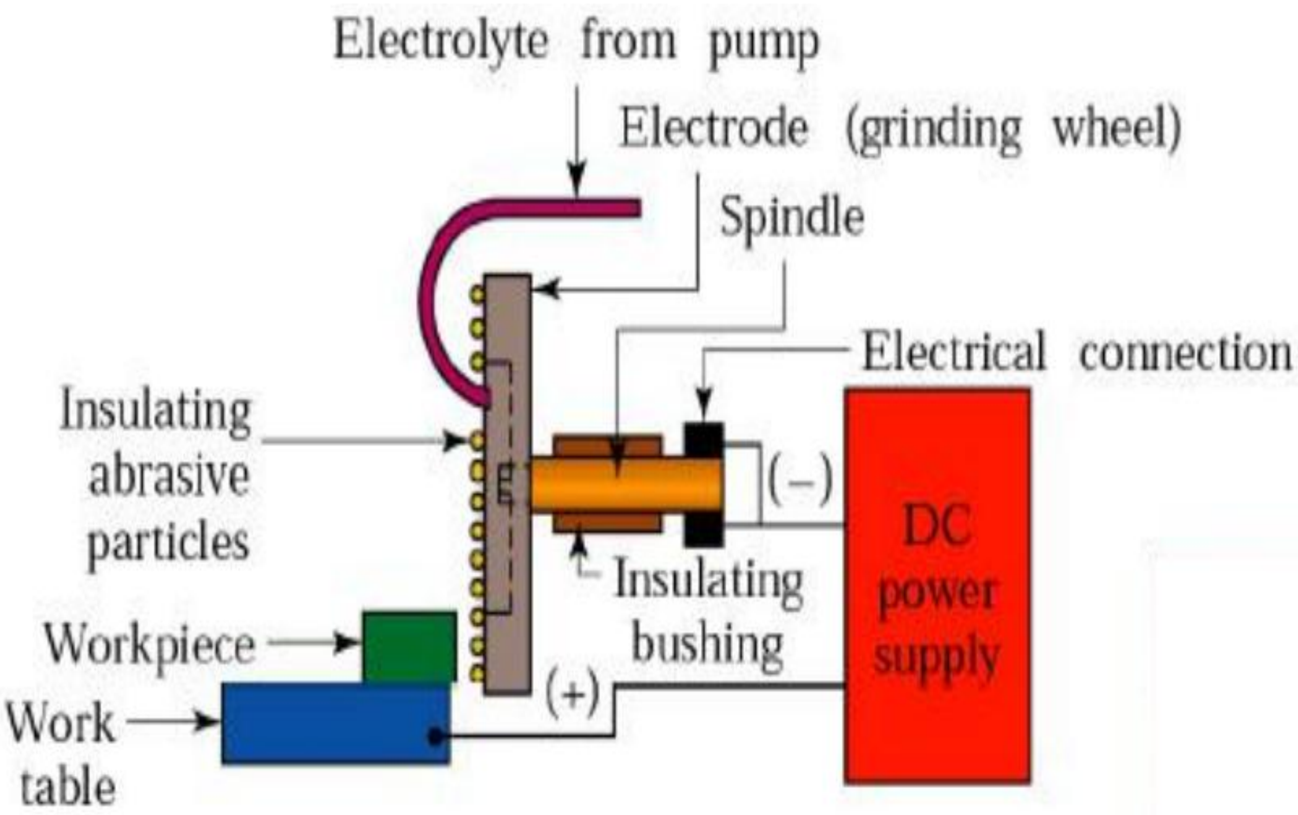
➢ Electrochemical Grinding (ECG), also called as electrolytic grinding is a variation process of the basic electrochemical machining (ECM), wherein material removal of the electrically conductive work material takes place through the combined effect of electrochemical process and the mechanical action of the abrasive particles (grinding) on the work material.





Electrochemical Grinding

The process makes use of a metallic grinding wheel which is embedded with insulating abrasive particles such as aluminum oxide or diamond, set in a conducting bonding material. The grinding wheel acts as a cathode, while the workpiece acts as anode.

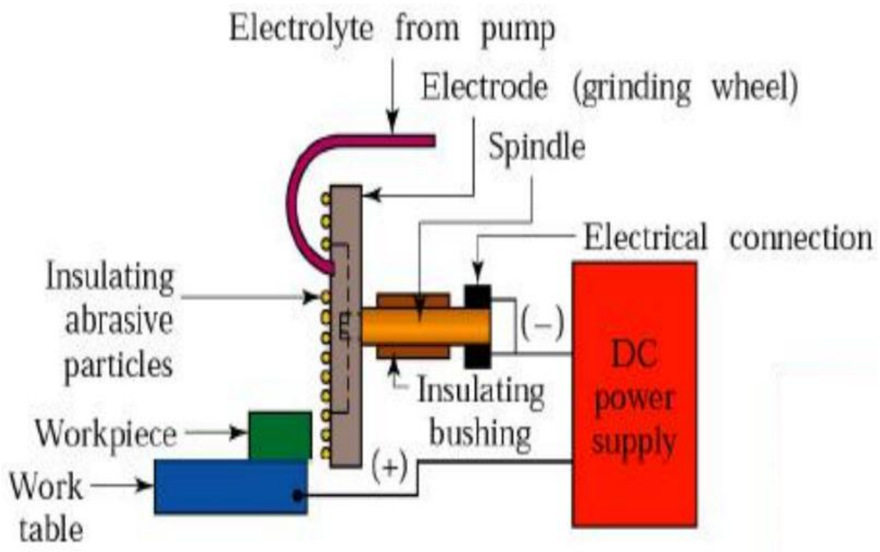


The electrolyte, usually sodium nitrate in water is supplied through a nozzle on to the grinding wheel near the workpiece such that the wheel carries it through the cutting process thereby resulting in an electrochemical action.

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 .

Electrochemical Grinding Process

- When a DC voltage of about 5-15V is applied between the workpiece and the grinding wheel, suitable current densities are created, removing material from the worksurface by electrochemical action coupled with the abrasive action of the grinding wheel.



- Nearly about 10% of the volume of the work material is removed by abrasive action of the wheel, while the remaining 90% by electrochemical action.
- The workpiece metal goes into solution as metal ions (anodic dissolution), and bubbles of hydrogen are generated at the wheel.

ADVANTAGES of ECG

a. Ability to grind any electrically conductive material regardless of hardness.

b. Metal removal rates are 5 to 10 times greater than broaching, milling or conventional grinding (for metals harder than HRC60).

c. Frequent grinding wheel dressing is unnecessary. Long wheel life and low wheel cost per volume of material removal.

d. Accuracy and surface finish are comparable.

e. High production rates are possible.

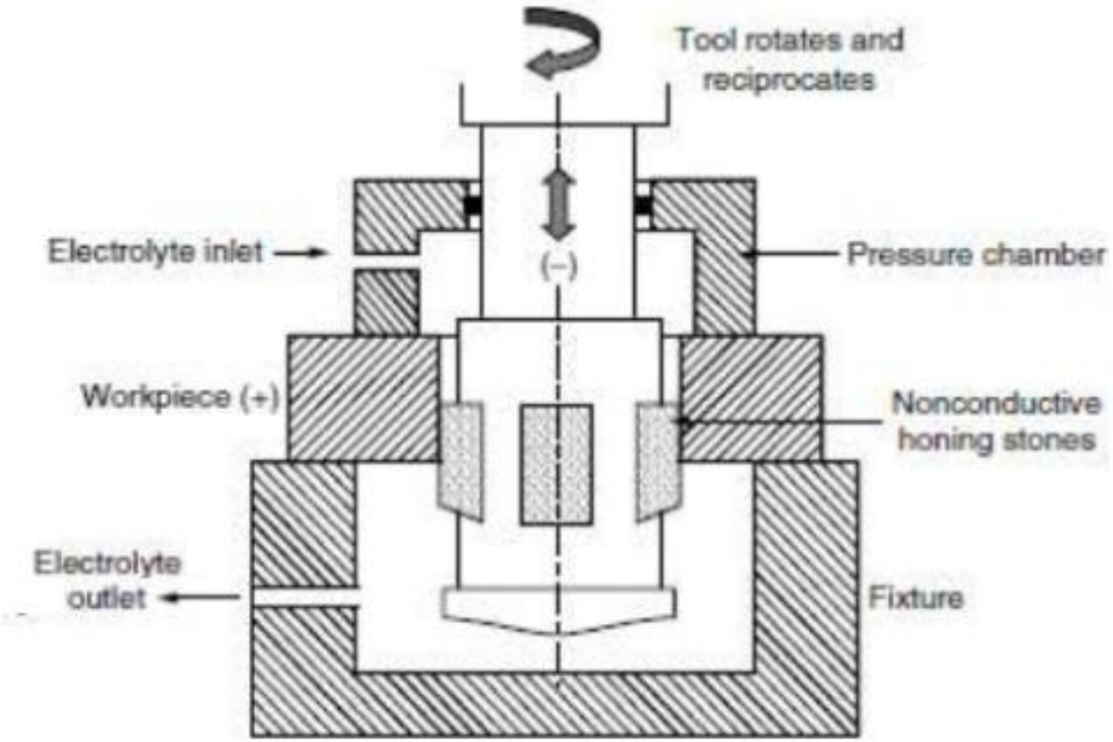
f. No distortion of thin and fragile parts. Workpiece is not subjected to overheating.

LIMITATIONS of ECG

a. Workpiece must be electrically conductive.
b. High equipment cost.
c. Not suitable for grinding low hardness metals.
d. Post cleaning of work and equipment parts is necessary in order to avoid corrosion effects of the electrolytes used.

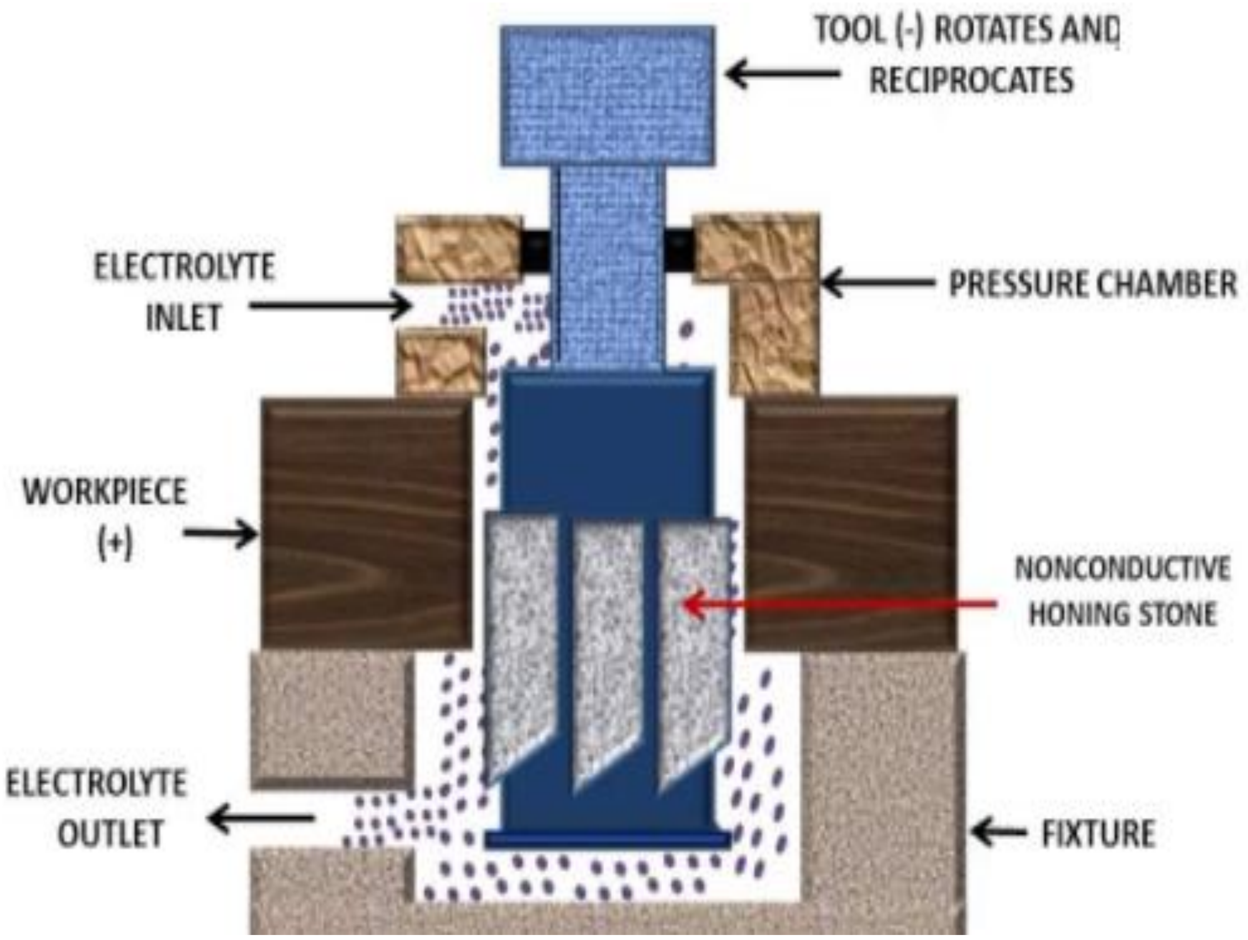
Electrochemical Honing

- Electrochemical honing is a modification of conventional honing, wherein material from the electrically conducting workpiece is removed by the combined effect of anodic dissolution of the work metal & mechanical abrasion action.



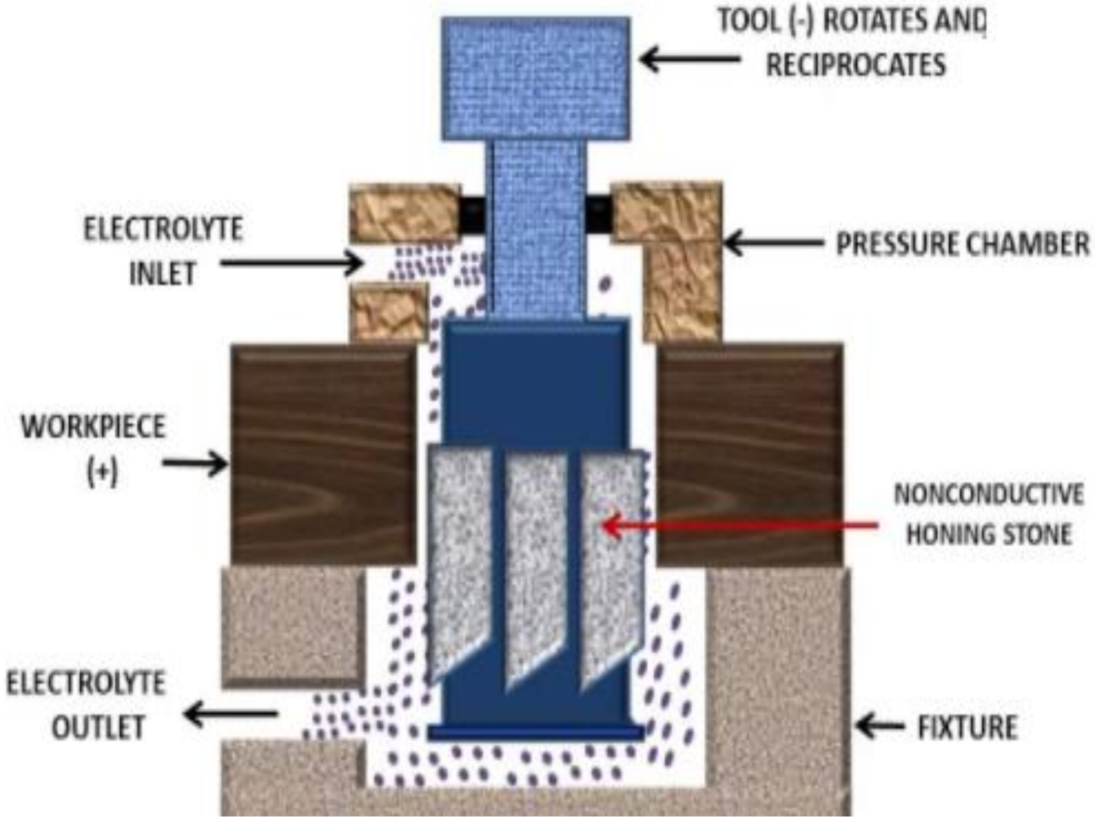
Electrochemical Honing

- The process makes use of a hollow stainless steel tool that acts as a cathode, while the workpiece, the anode. The tool is rotated and reciprocated on a rigid spindle for precise metal removal from internal cylindrical hole of the workpiece metal.
- Bonded abrasive stones protrude or extend from at least three locations around the circumference of the tool as shown in the figure. The length of the honing stone is about half the length of the bore to be honed. The stones are non-conductive and assist in electrochemical action.



Electrochemical Honing

- A suitable electrolyte such as sodium chloride or sodium nitrate is supplied under pressure (pumped) through the hollow tool body, which in turn exits through the holes provided in the tool body , and then into the tool workpiece gap.
- As the cutting tool rotates and reciprocates in the workpiece hole, material is removed by the combined action of electrochemical dissolution and abrasive action of the stones.



- As material is removed from the hole (bore), the stones expand to maintain constant contact against the work surface , the process continuous until the required finish is obtained.

ADVANTAGES of ECH

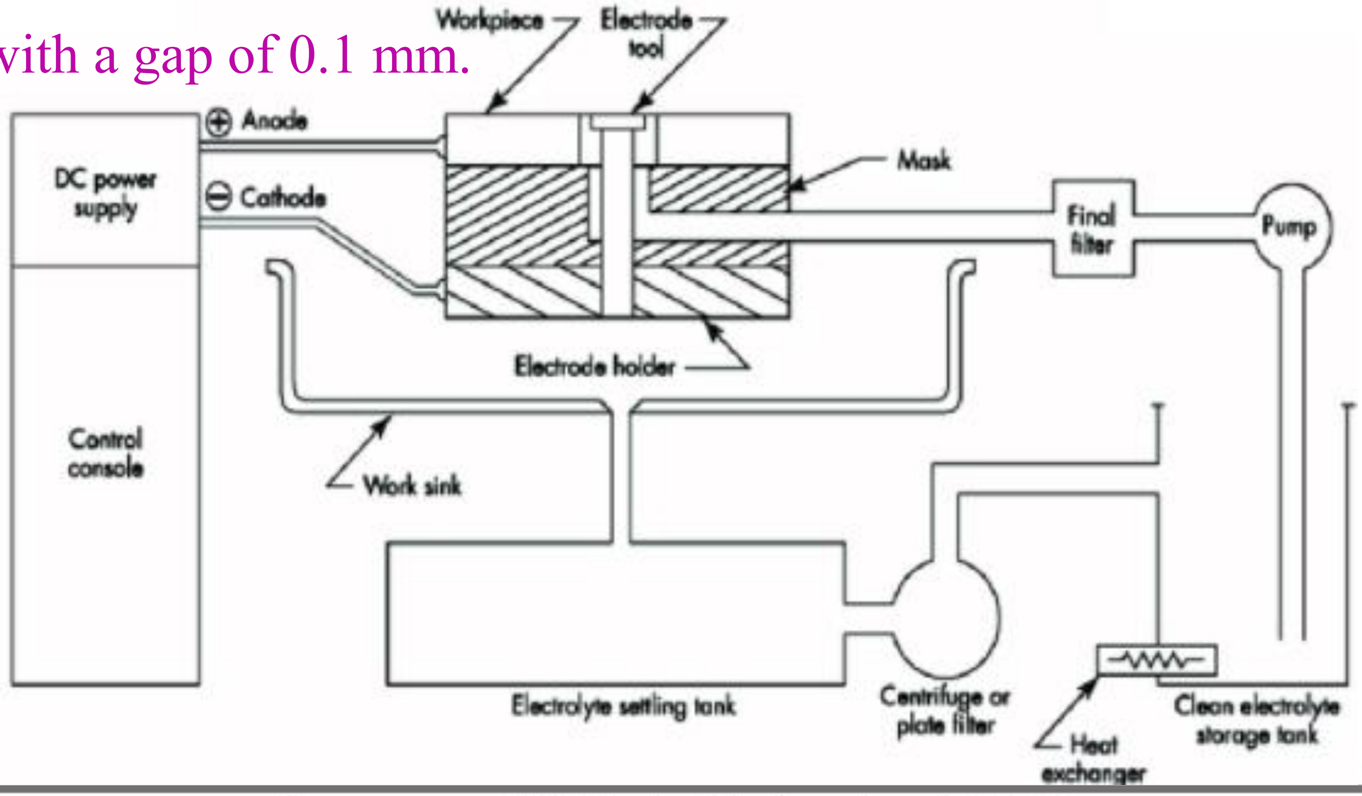
a. Ability to grind any electrically conductive material regardless of hardness .
b. Burr - free action
c. Surface finish and accuracy are far comparable to conventional honing.
d. Reduced noise and distortion
e. High production rates are possible.
f. Machining is primarily by electrochemical dissolution and hence results in stress –free machining and less low heat generation compared to conventional honing.

LIMITATIONS of ECH

a. Workpiece must be electrically conductive.
b. High equipment cost.
c. Post cleaning of work and equipment parts is necessary in order to avoid corrosion effects of the electrolytes used.
d. High maintenance.

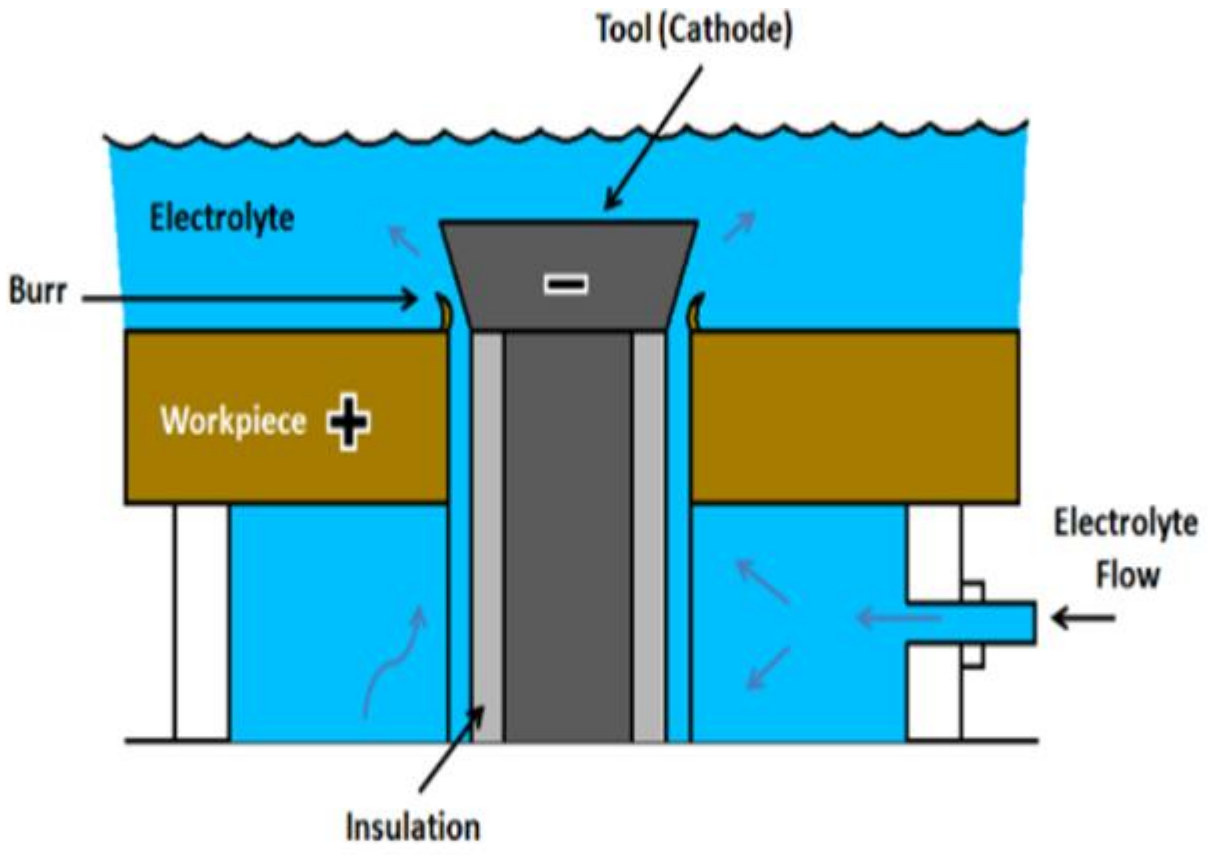
Electrochemical Deburring

- ➢ Electrochemical Deburring is a non- traditional secondary machining process used to remove metallic burrs resulting from primary machining and forming operations
- o In electrochemical deburring, the cathode tool and the anode workpiece is placed in a fixed relative position with a gap of 0.1 mm.



Electrochemical Deburring

- The tool is insulated on all surfaces except those adjacent to the burr. The tool is positioned in a close proximity, usually near the base of the burr
- As in ECM process, the electrolyte, sodium nitrate is pumped through the gap between the burr and the tool.
- Depending on the burr size and finish required, a suitable current is supplied to the workpiece the burrs get dissolved from the workpiece electrochemically and are flushed away by the flowing electrolyte



Electrochemical Deburring

ADVANTAGES of ECD

a. Precise deburring at the defined points .
b. Faster than conventional deburring
c. Suitable for material of any hardness
d. No forming of secondary burrs
e. Neither thermal nor mechanical stresses on the components.
f. Suitable for mass production.

LIMITATIONS of ECD

a. Limited to conductive work materials.
b. Burrs should be of consistent shape and size.
c. Not suitable for small productions.
d. High equipment cost.
e. Post cleaning of work and equipment parts is necessary in order to avoid corrosion effects of the electrolytes used.

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Chemical Machining (CHM)

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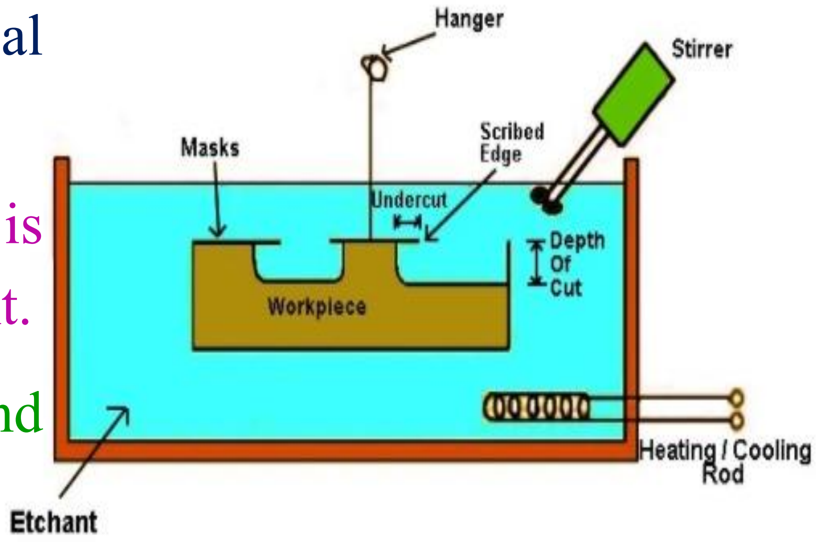
CHEMICAL MACHINING (CHM)

- Elements of the process: Resists (maskants), Etchants.
- Types of chemical machining process-chemical blanking process, chemical milling process.
- Process characteristics of CHM: material removal rate, accuracy, surface finish,
- Advantages, limitations and applications of chemical machining process.

Principle of Chemical machining

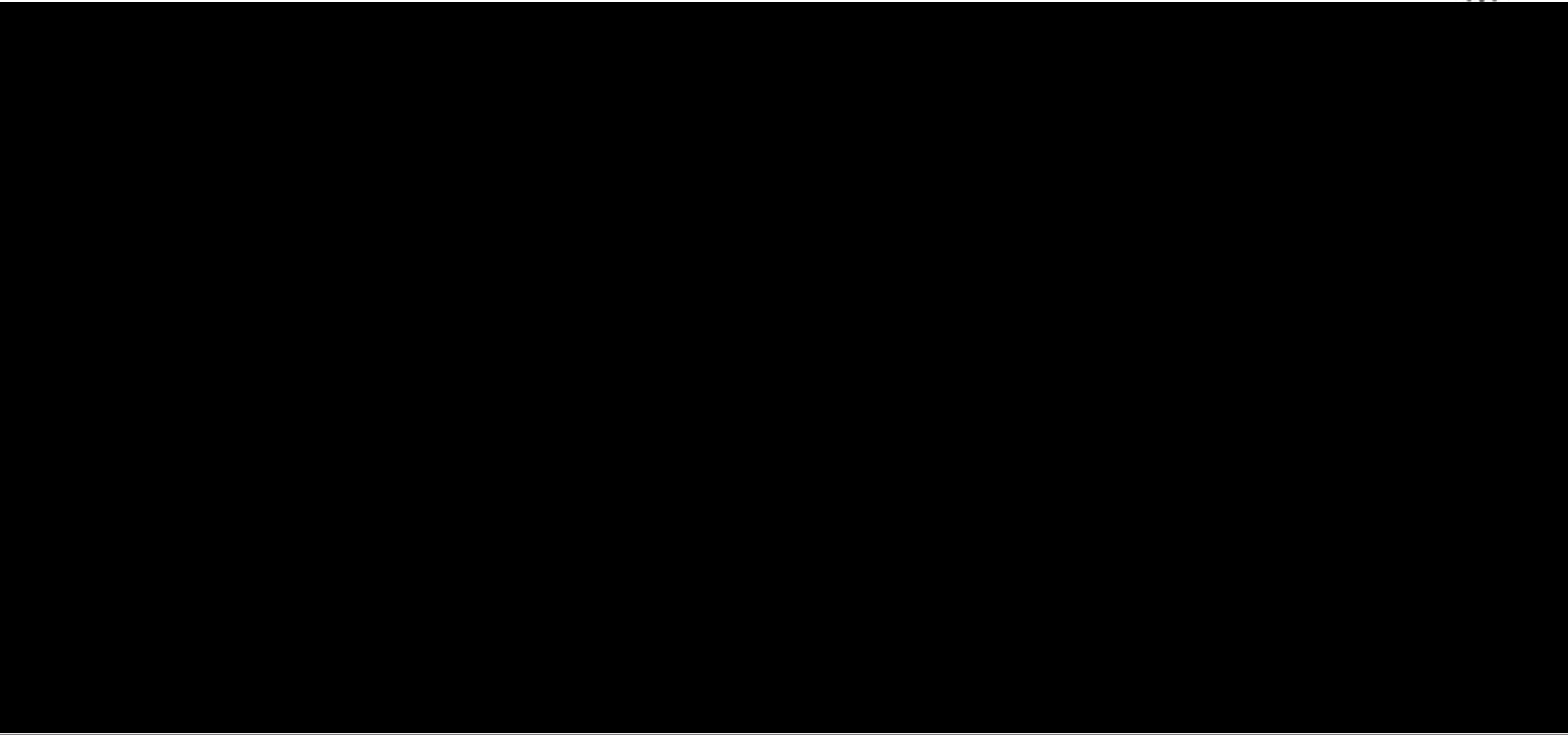
DEFINITION: Chemical machining is a controlled chemical dissolution of the work material by means of contact with a strong acidic or alkaline chemical reagent.

- The working principle of chemical machining is based on chemical etching.
- The part of the workpiece metal where material is to be removed is brought into contact with a strong corrosive chemical called etchant.
- The etchant reacts with the work material in the area to be cut and causes the solid work material to be dissolved.
- Thus the metal is removed by the chemical attack of the etchant.



Chemical Machining

- The portion of the work material where material is not to be removed is protected from chemical attack by means of special coatings called maskants.
- Nearly all materials from metals to ceramics can be machined with chemical machining process.



Elements of Chemical Machining

01

ETCHANTS

02

MASKANTS

Elements of Chemical Machining Process

Basically there are two elements involved in the CHM process:

- **Etchants**
- **Resists or maskants**

a) Etchants

- Etchants are acid or alkaline solutions maintained within a controlled range of chemical composition and temperature.
- The workpiece material to be removed is sprayed or immersed in a suitable etchant.
- The etchant reacts with the work material in the area to be cut and causes the solid work material to be dissolved in it.

b) Resists or Maskants

- Maskants are polymer or rubber based materials, generally used to protect portion of the workpiece material where chemical dissolution action is not needed.
- In other words, maskants protects the portion of the workpiece metal where material is not to be removed by the chemical action of the etchant.

Elements of Chemical Machining Process

1. Etchants

The type of etchant to be selected for machining is based on the following factors:

(1) Type of workpiece metal that is being etched.

The potential damage to the surface and/or metallurgical properties of work material resulting from the etchant need to be considered.

(2) Depth of etch required.

(3) Rate of metal removal

(4) Surface finish required

(5) Type of maskant used

(6) Un-harmful to human operators.

(7) Ability to regenerate the etchant solution and/or readily neutralize & dispose of its waste products

(8) Availability and low cost

Elements of Chemical Machining Process

Etchants

Sl. No.	Work material	Chemical etchant	Etching temperature (°C)	Etch rate (mm/min)
1.	Aluminum & alloys	$FeCl_3$	49	0.013 – 0.025
2	Copper & alloys	$FeCl_3$ $CuCl_2$	49 54	2 1
3.	Steel	$FeCl_3$	54	0.025
4.	Nickel	$FeCl_3$	49	0.13 – 0.38
6.	Magnesium	HNO_3	32 – 49	1
7.	Titanium	HF	–	–
8.	Glass	HF / $HF + HNO_3$	–	–

Elements of Chemical Machining Process

2. Resists or Maskants

- Maskants are polymer or rubber based materials, generally used to protect portion of the workpiece material where chemical dissolution action is not needed.
- In other words, maskants protects the portion of the workpiece metal where material is not to be removed by the chemical action of the etchant.
- The maskant can be applied on the work material by various methods like dip, brush, spray, roller, electro-coating, and as well as adhesive tapes.
- Sometimes, multiple coats of maskant are frequently used to increase the etchant resistance and avoid the formation of pinholes on the machined surfaces.

Elements of Chemical Machining Process

2. Resists or Maskants

The type of maskant to be selected for machining is based on the following factors:

(1) Chemical resistance required.

(2) Be inert to the chemical reagent used

(3) Be tough enough to withstand handling

(4) Adhere well to the workpiece surface

(5) Allow itself to be scribed easily

(6) Be removed easily and inexpensively after etching

(7) Be able to withstand the heat generated by etching

(8) Availability and low cost.

Elements of Chemical Machining Process

Maskants

Sl. No.	Work material	Maskant material
1.	Aluminum & alloys	Polymer, Butyl rubber & neoprene.
2	Copper & alloys	Polymer
3.	Iron based alloys	Polymer, poly vinyl chloride, polyetilien butyl rubber
4.	Nickel	Neoprene
6.	Magnesium	Polymer
7.	Titanium	Polymer

Steps in Chemical machining

1. Preparing: precleaning
2. Masking: application of chemically resistant material (if selective etching is desired)
3. Etching: dip or spray exposure to the etchant
4. Remove mask: strip remaining mask and clean
5. Finish: inspection and postprocessing

Steps in Chemical machining

1. Preparing: precleaning

- The work piece material has to be cleaned in the beginning of chemical machining process.
- The cleaning operation is earned out to remove the oil, grease, dust, rust or any substance from the surface of material.
- A good cleaning process produces a good adhesion of the masking material.
- There are two cleaning methods: mechanical and chemical methods.
  - The most widely used cleaning process is chemical method due to less damages occurred comparing to mechanical one.
  - Ultrasonic cleaning machine is applied with using special cleaning solution and heating is beneficial during the cleaning process.

Steps in Chemical machining

2. Masking:

Coating with masking material

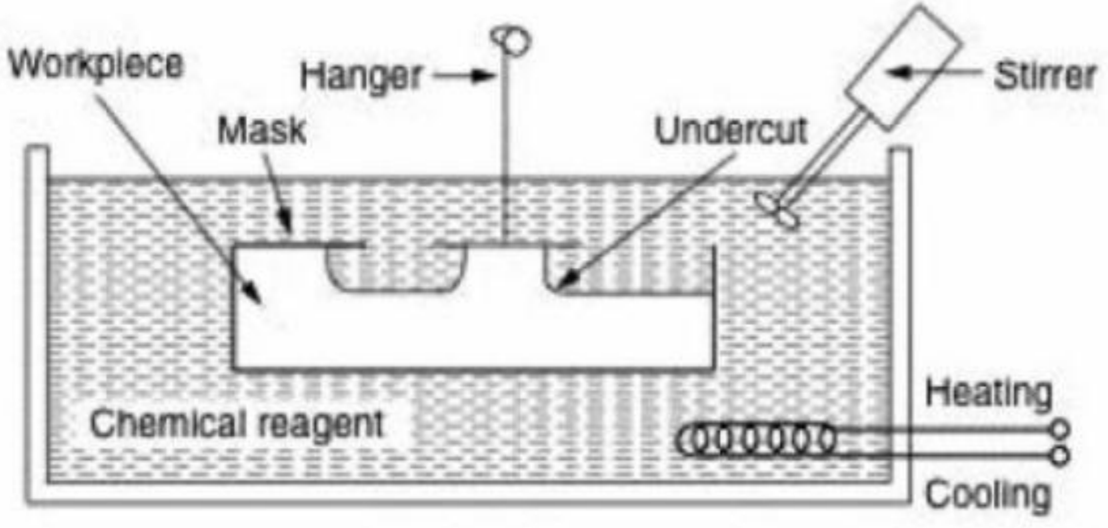
- The next step is the coating cleaned workpiece material with masking material.
- The selected masking material should be readily strippable mask, which is chemically impregnable (impenetrable) and adherent enough to stand chemical abrasion during etching.

Scribing of the mask

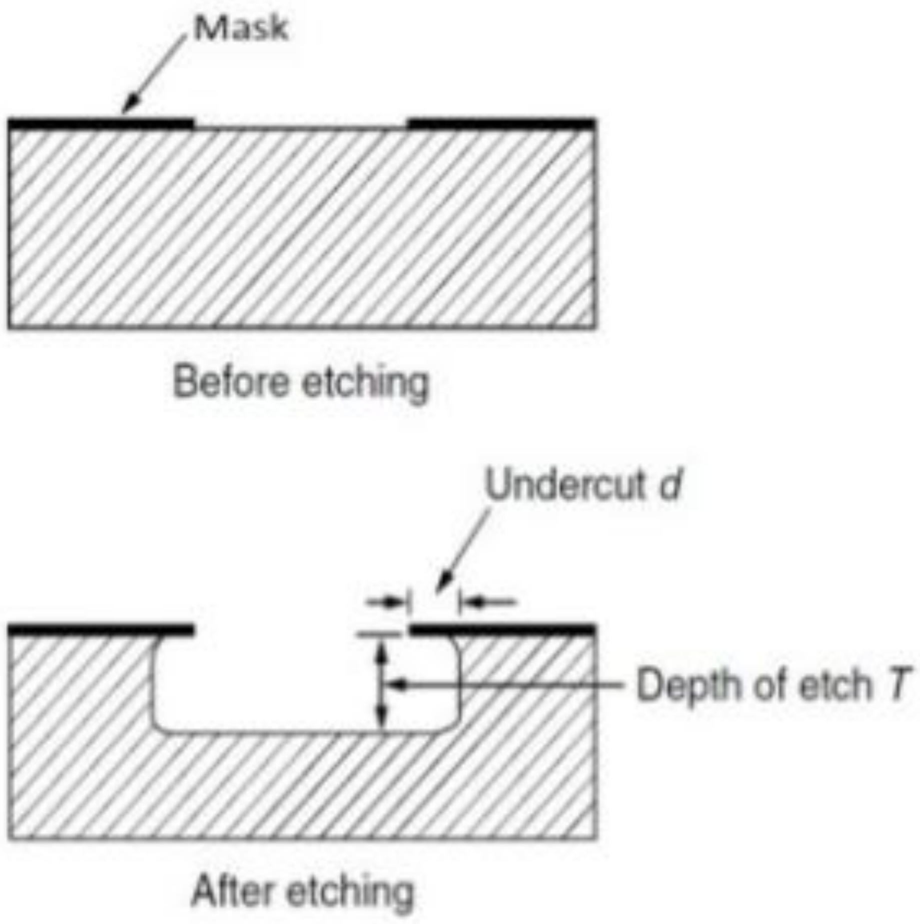
- This step is guided by templates to expose the areas that receive chemical machining process.
- The selection of mask depends on the size of the workpiece material, the number of parts to be produced, and the desired detail geometry.

Steps in Chemical machining

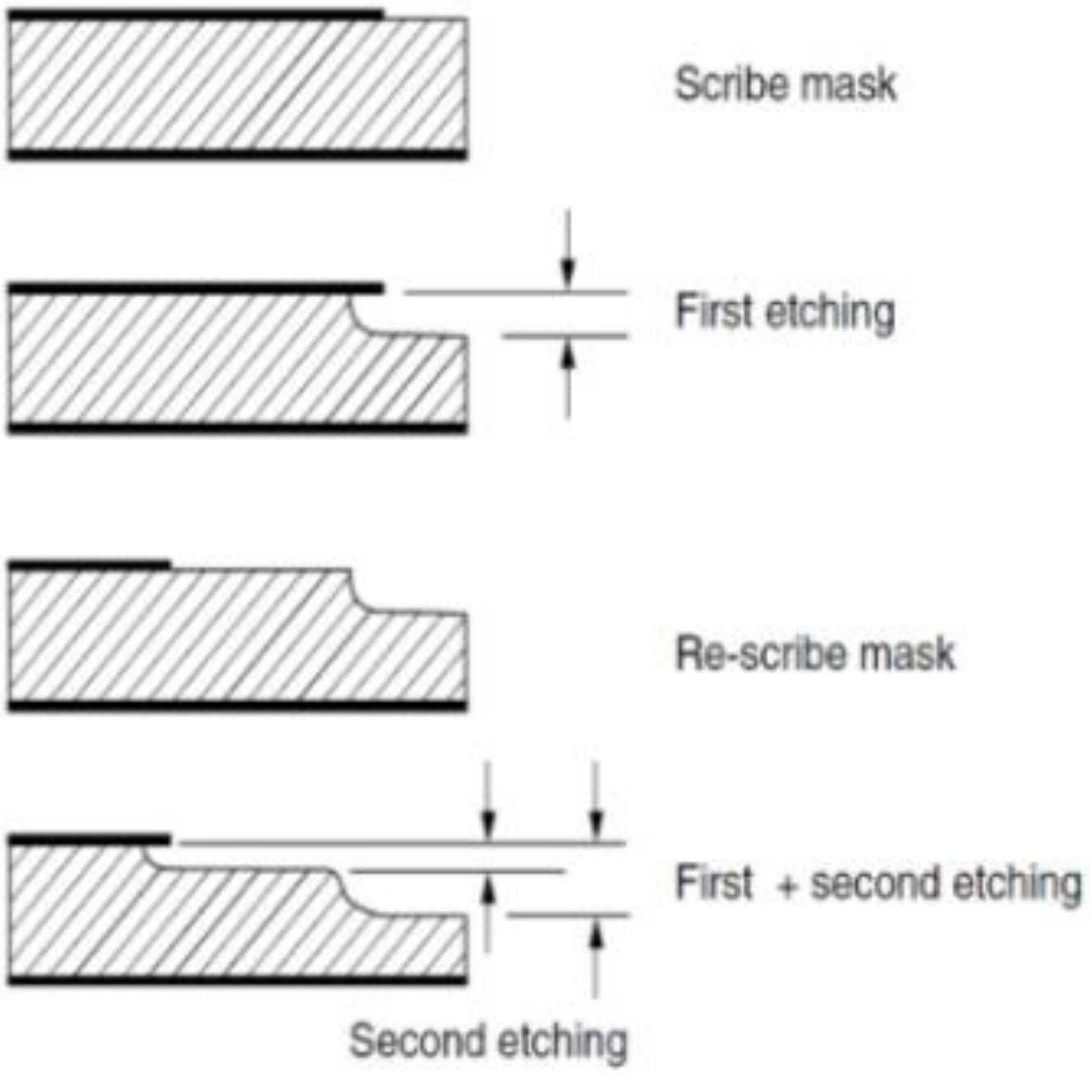
3. Etching



- This step is the most important stage to produce the required component from the sheet material.
- This stage is carried out by immerse type etching machine
- The workpiece material is immersed into selected etchant and the uncovered areas are machined.
- This process is generally carried out in elevated temperatures which are depended on the etched material.
- Then the etched workpiece is rinsed to clean etchant from machined surface.



Etch factor after CHM



Contour cuts by CHM.

Steps in Chemical machining

4. Cleaning masking material

- Final step is to remove masking material from etched part. The inspections of the dimensions and
- Surface quality are completed before packaging the finished part.

MASKING METHODS

01

Cut and Peel method

02

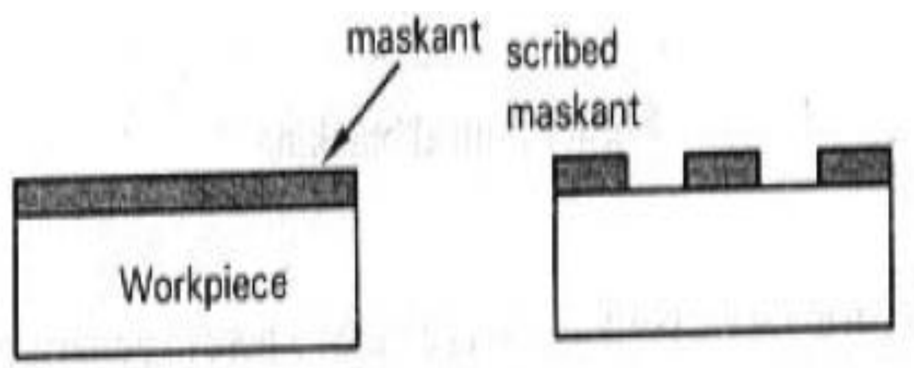
Photographic Resist Method

03

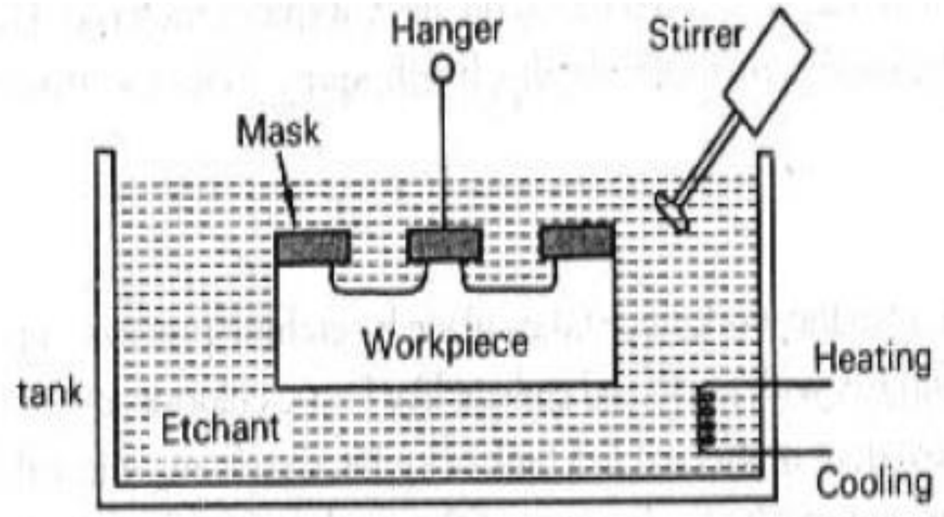
Screen Resist Method

Masking Methods

1. Cut and Peel method



- In this method, the maskant is initially applied on a large surface area and then scribed or cut with a sharp knife followed by careful peeling of the mask from the selected areas to be etched as shown in figure.
- This method is used for those applications where thick maskants are laid on worksurface due to the necessity for withstanding high exposure to the etchant for extended periods.
- Since scribing the maskant is done with a knife, this method of maskant is used where accuracy of the surface generated is not a critical factor.



Masking Methods

2. Photographic Resist Method

- In this method, the mask is applied on the work surface using photographic techniques.
- The masking material contains photosensitive chemicals, which are exposed to light through a negative image of areas to be etched.
- These areas are then removed using photographic developing techniques, while the remaining areas are vulnerable to etching.
- This method is suitable for small parts that are required to be produced in large quantities. Fabrication of integrated circuits and printed circuit boards make use of this method.

Masking Methods

3. Screen Resist Method

- Screen resists or maskants are materials that can be used on the workpiece through normal silk screening techniques.
- The maskant is painted through a silk or stainless steel mesh, which has areas blocked off to allow selective passage for the maskant.
- The blocked pattern corresponds to the image that is to be etched. The screen is pressed against the work surface and the maskant is rolled on.
- When the screen is removed, the maskant remains on the work part in the desired pattern. The image accuracy is better than that achieved by other types of maskants.

Types of Chemical Machining

01

Chemical Blanking

02

Chemical Milling

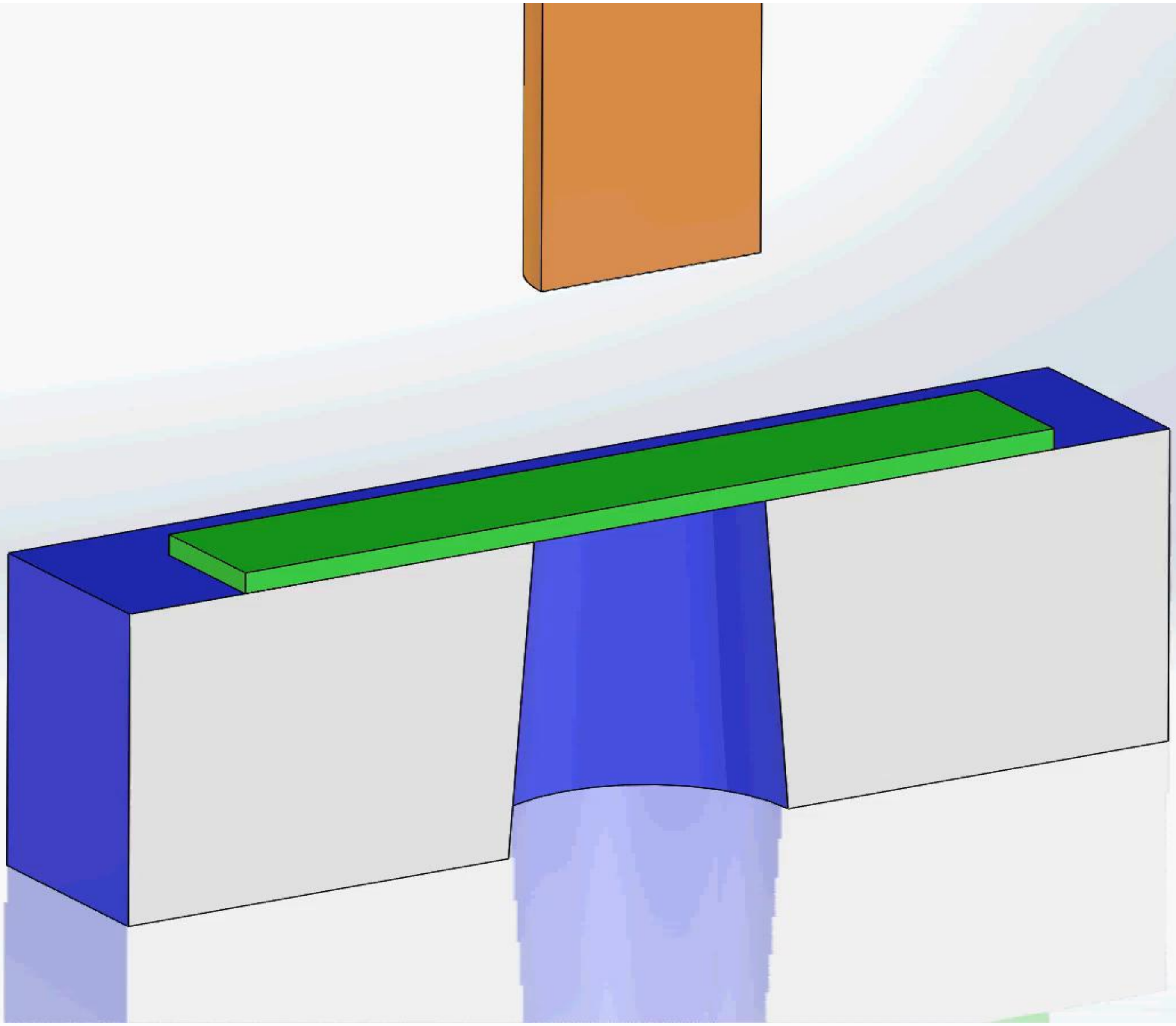
Chemical Blanking

Chemical blanking is a process of producing a part from thin sheet metal or strip by chemically etching the periphery of the desired shape.

Typical applications of chemical blanking include: burr-free etching of printed-circuit boards, decorative panels, thin sheet metal stampings, as well as the production of complex or small shapes in work parts.

Chemical blanking involves the following processing steps :

- Workpiece pre-cleaning process
- Masking
- Etching and
- De-masking


Solidworks Fun
By: Praveen Singh

Chemical Blanking

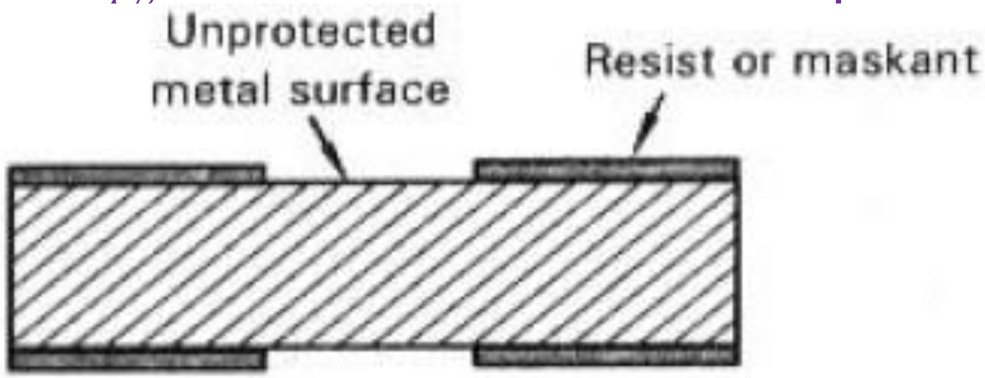
1. Workpiece pre-cleaning process

- The surface of the workpiece metal is cleaned thoroughly, degreased and pickled by acid or alkalis.
- Pre-cleaning is of utmost importance in order to remove oil, grease, dirt, rust, or any foreign substances from the work surface so as to produce a good adhesion of the masking material.
- The material is allowed to dry to before masking.

Chemical Blanking

2. Masking

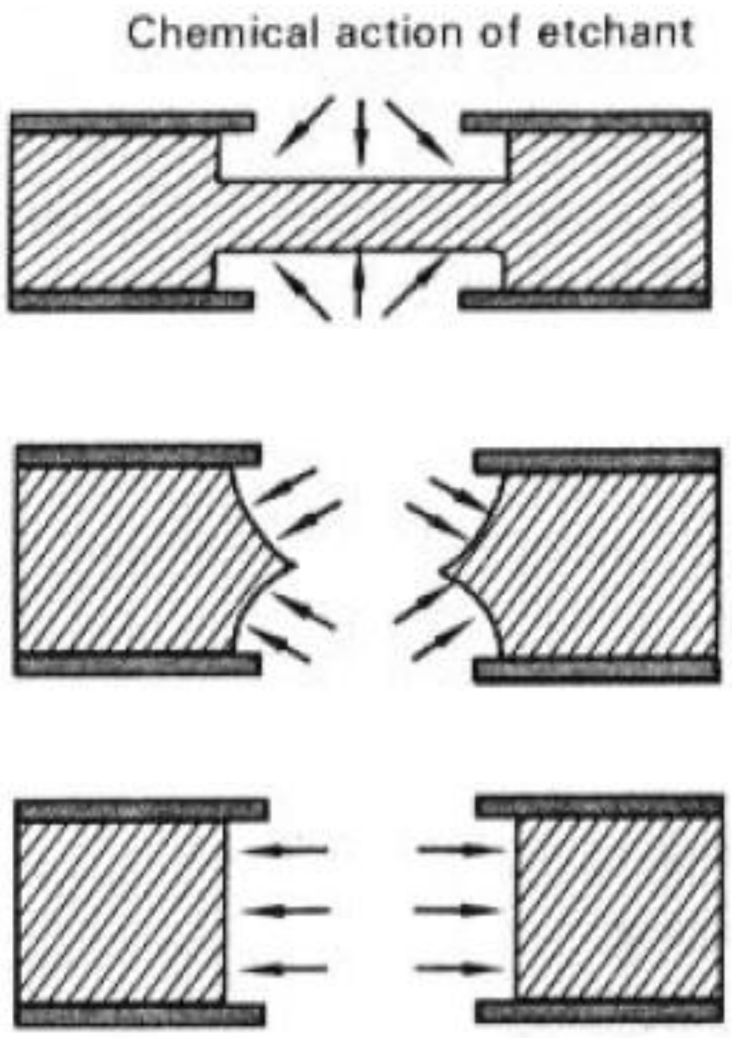
- Masking involves covering the portions of the workpiece metal where material is not to be removed by the chemical action of the etchant.
- A suitable maskant, say a polymer, rubber, or any other material is selected based on the workpiece material.
- The maskant is applied on the work surface by various methods like dip, brush, spray, roller, electro-coating, and as well as adhesive tapes.



Chemical Blanking

3. Etching

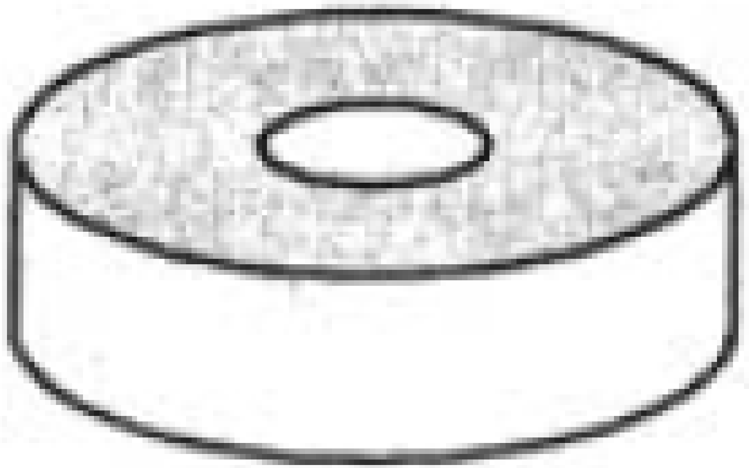
- Removal of material from the workpiece takes place by etching process.
- The workpiece metal is either sprayed continuously with a selected etchant like Ferric chloride, on those portions where the material is to be removed, or immersed in a tank of agitated etchant, where the etchant chemically attacks those portions not masked.
- Erosion of the work material takes place both inward and laterally from the exposed (unmasked) surface
- The work material is converted into metallic salt, which is then dissolved and carried away in the etchant solution.



Chemical Blanking

4. De-masking

- When etching is completed, the mask is removed either through mechanical or chemical means. Any etchant on the work material is also removed with a wash or clear, cold water.
- A deoxidizing bath may also be required in order to remove the oxide films left on the surface of the work material.



Chemical Milling or Contour Machining

Chemical milling is a process used to produce shapes by chemically etching selective portion of material from the relatively large surface area of work metal.

Typical applications include producing shallow cavities with complex profiles on plates, sheets, forgings, generally for the overall reduction of weight.

Chemical Milling involves the following processing steps :

- Workpiece pre-cleaning process
- Masking and Scribing mask
- Etching and
- De-masking

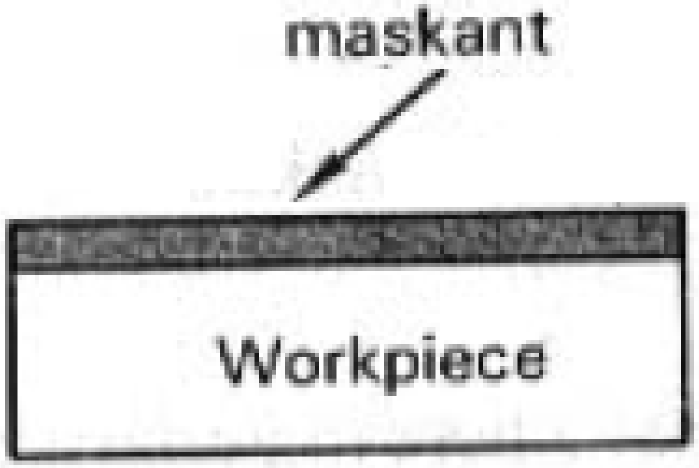
Chemical Milling

1. Workpiece pre-cleaning process

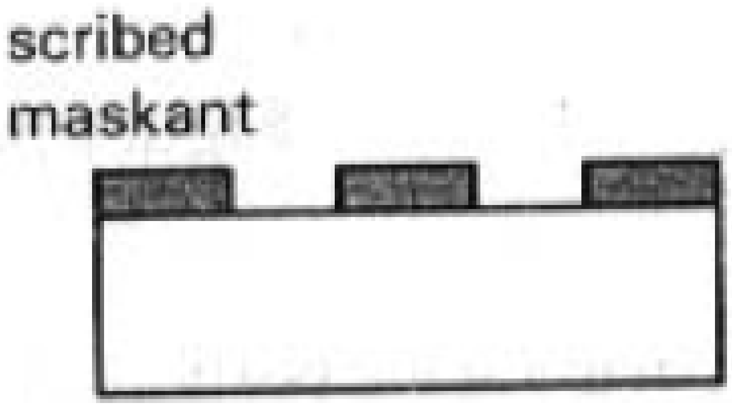
- The surface of the workpiece metal is cleaned thoroughly, degreased and pickled by acid or alkalis.
- Pre-cleaning is of utmost importance in order to remove oil, grease, dirt, rust, or any foreign substances from the work surface so as to produce a good adhesion of the masking material.
- The material is allowed to dry to before masking.

Chemical Milling

2. Masking

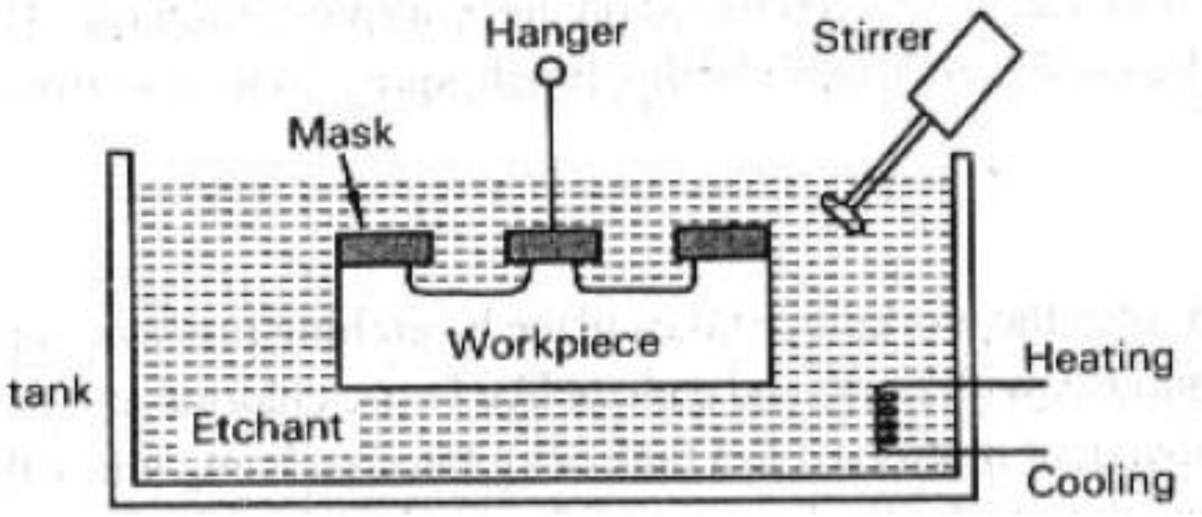


- Masking involves covering the portions of the workpiece metal where material is not to be removed by the chemical action of the etchant.
- Masking with adhesive tapes or paints (maskants) is a common practice, although elastomers (rubber and neoprene) and plastics (polyvinyl chloride, polyethylene, and polystyrene) are also used.
- Since it is very difficult to apply maskants on small surfaces, the maskant is initially applied on a large surface area and then scribed or cut with a sharp knife followed by careful peeling of the mask from the selected areas to be etched.



Chemical Milling

3. Etching



- The un-masked (exposed) surfaces of the work material are machined chemically with selected etchants.
- Etching is carried out by immersing the work material in a tank of agitated etchant.
- The process is carried out at higher temperatures depending on the etched material. Temperature control and agitation (stirring) during chemical milling is important in order to obtain a uniform depth from the material removed.
- Erosion of the work material takes place from the exposed (unmasked) surface.

Chemical Milling

4. De-masking

- When etching is completed, the mask is removed either through mechanical or chemical means. Any etchant on the work material is also removed with a wash or clear, cold water.
- A deoxidizing bath may also be required in order to remove the oxide films left on the surface of the work material.

Process Capability or Process Characteristics of Chemical machining

- The various parameters involved in chemical machining include: the type of etchant, its concentration, operating temperature, and circulation.
- The process is also affected by the maskant and its application.
- These parameters have been found to have direct impact on the accuracy, surface finish and metal removal rate.
- The major factors that define the process characteristics of chemical machining are as follows
  - Metal removal rate
  - Accuracy
  - Surface Finish

Process Capability or Process Characteristics of Chemical machining

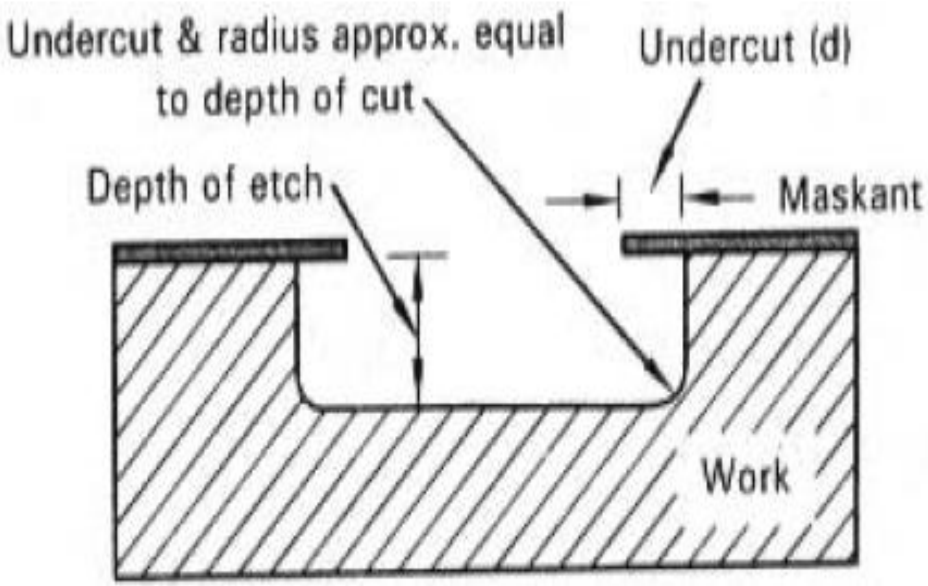
1. Metal removal rate

- The metal removal rate or etch rate mainly depends on the type of etchant used.
- Etchants that remove metal faster tend to have many side effects including reduction in surface finish, increased undercut, higher heating, and attack on the bond between the maskant and the work surface.
- The etch rate is normally limited to 0.02 to 0,04 mm/min when surface finish and accuracy are not important.

Process Capability or Process Characteristics of Chemical machining

2. Accuracy

- The accuracy obtained in chemical machining depends on the undercut produced. Undercut per edge is approximately equal to the depth of cut as shown in figure.
- The allowance for undercut is provided in the design stage itself. The tolerance on depth of cut increases when machining larger depths at high machining rates.
- Aluminum and magnesium alloys can be controlled more closely than steel, nickel or titanium alloys. Under optimum conditions of time, temperature and solution control, accuracies of the range of $\pm 0.01\, mm$ can be achieved.



Process Capability or Process Characteristics of Chemical machining

3. Surface Finish

- The machining rate affects the surface roughness and hence the tolerance produced.
- Generally, slow etching will produce a surface finish similar to the original surface.
- The surface roughness is influenced by the initial workpiece roughness. It increases as the metal ion concentration rises in the etchant. For low machining depths. <200pm, the roughness sharply increases with the depth of cut.
- Typically, surface roughness of 0.1 to 0.8 μm, depending on the initial roughness, can be achieved. However, under special conditions, roughness of the order 0.025 to 0.05 μm is also possible.

Advantages of CHM

- Many work parts can be etched simultaneously.
- No burrs are formed.
- No stress is introduced to the workpiece, which minimizes the part distortion and makes machining of delicate parts possible.
- Low capital investment.
- Design changes can be implemented quickly.
- Less skilled operator is sufficient to operate.
- Tooling costs are minor.
- Good surface quality in addition to the absence of burrs eliminates the need for finishing operations.

Limitations of CHM

- Limited depth of cut.
- Difficult to produce sharp radius. Fillet radius is fixed by the depth of cut.
- Handling and disposal of chemical could be troublesome. Also, difficult to maintain clean work environment.
- Metallurgical homogenous work surface is required for best machining results

Applications of Chemical machining

- Shallow cuts in large thin sheets for weight reductions in pre-formed aerospace components is the major application of chemical machining.
- CHM is used to thin out walls, webs, and ribs of parts that have been produced by forging, casting, or sheet metal forming.
- Also used for process applications related to improving surface characteristics like elimination of decarburized layer from low alloy steel forgings, elimination or recast layer from parts machined by EDM process, etc.
- Engraving highly intricate details on any metal piece is another important application of chemical machining.