Unit II

CHEMICAL AND ELECTRO CHEMICAL ENERGY BASED PROCESSES

Working principle, elements, advantages, limitations and applications of chemical machining (Chemical milling)**.**

- This process is also called etching. The mechanism is to use chemical reaction between the material of the work piece and some chemical reagent, so that the products of the reaction can be removed easily. Thus the surface of the work piece is etched away, exposing the lower layers, and the process is continued until the desired amount of material is removed.

- The chemical machining processes include those wherein material removal is accomplished by a chemical reaction, sometimes assisted by electrical or thermal energy applications. This group includes chemical milling, photochemical machining, and thermo chemical machining.

- Chemical machining or Chemical milling (CHM) is a well known nontraditional machining process is the controlled chemical dissolution of the machined work

- piece material by contact with a strong acidic or alkaline chemical reagent.

- Special coatings called maskants protect areas from which the metal is not to be removed. The process is used to produce pockets and contours and to remove materials from parts having a high strength-to-weight ratio.

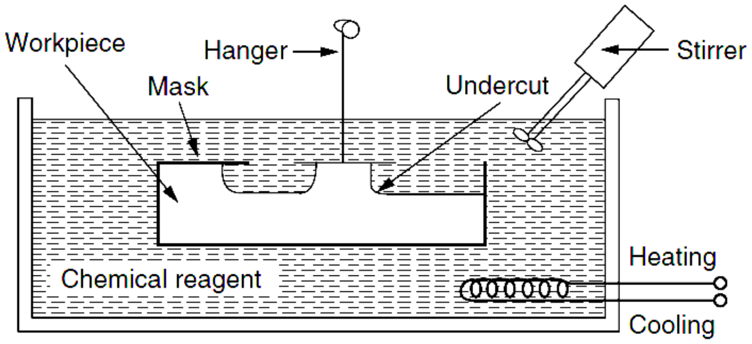
CHM consists of the following steps:

1. Preparing and pre-cleaning the work piece surface. This provides good adhesion of the masking material and assures the absence of contaminants that might interfere with the machining process.
2. Masking using readily strippable mask, which is chemically impregnable and adherent enough to stand chemical abrasion during etching.
3. Scribing of the mask, which is guided by templates to expose the areas that receive CHM. The type of mask selected depends on the size of the work piece, the number of parts to be made, and the desired resolution of details. Silk-screen masks are preferred for shallow cuts requiring close dimensional tolerances.
4. The work piece is then etched and rinsed, and the mask is removed before the part is finished.

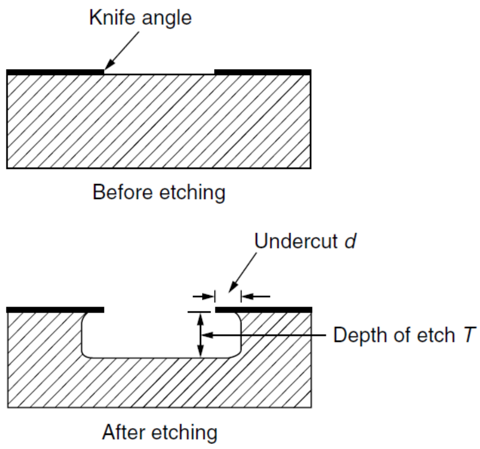
- During CHM (Fig.), the depth of the etch is controlled by the time of immersion. In order to avoid uneven machining, the chemicals that impinge on the surface being machined should be fresh. The chemicals used are very corrosive and, therefore, must be handled with adequate safety precautions. Both the vapors and the effluents must be suitably controlled for environmental protection.
- Agitation of the work piece and fluid is usual; however, excessive solution flow may result in channeling, grooves, or ridges. Inclination of the

workpiece may prevent channeling from gas bubbles.

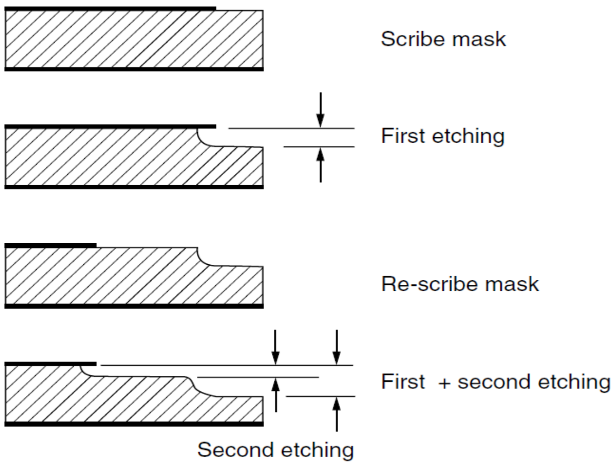
- Bellows (1977) and the Metals Handbook (1989) reported that dishing of the machined surface occurs due to the uneven heat distribution resulting from the chemical action. Typical reagent temperatures range from 37 to 85°C. Faster etching rates occur at higher temperatures, but must be controlled within ±5°C of the desired temperature in order to attain uniform machining.



- When the mask is used, the machining action proceeds both inwardly from the mask opening and laterally beneath the mask thus creating the etch factor shown in Fig. The etch factor is the ratio of the undercut d to the depth of etch T. This ratio must be considered when scribing the maskusing templates.



Etch factor after CHM.



Contours cut by CHM

- A typical etch factor of 1:1 occurs at a cut depth of 1.27 mm. Deeper cuts can reduce this ratio to 1:3. The radii of the fillet produced will be approximately equal to the depth of etch. For simultaneous machining of multiple parts, racks or handling fixtures are frequently used to facilitate the submersion of the work in the chemical reagent and for subsequent rinsing.
- After rinsing the chemicals from the workpiece, the demasking is accomplished by hand stripping, mechanical brushing, or chemical stripping. Some chemicals leave a film of smut on the machined surface, which can be removed by other chemicals or frequently by brushing.
- CHM will not eliminate surface irregularities, dents, scratches, or waviness. Successive steps of mask removal and immersion as shown in Fig. can achieve stepped cuts. Tapered cuts (Fig.), can also be produced without masking the work piece by controlling the depth and rate of immersion or withdrawal and the number of immersions. Continuous tapers, as great as 0.060 mm/mm for aluminum and 0.010 mm/mm for steel alloys, have been machined on a production basis.

ADVANTAGES: (MAY/JUNE 2013)

- Weight reduction is possible on complex contours that are difficult to machine using conventional methods.
- Simultaneous material removal, from all surfaces, improves productivity and reduces wrapping.
- No burrs are formed.
- No stress is introduced to the workpiece, which minimizes the part distortion and makes machining of delicate parts possible.
- A continuous taper on contoured sections is achievable.
- The capital cost of equipment, used for machining large components, is relatively low.
- Design changes can be implemented quickly.
- A less skilled operator is needed.
- Tooling costs are minor.
- The good surface quality in addition to the absence of burrs eliminates the need for finishing operations.
- Multiple parts having fine details can be machined by the gang method.
- Decorative finishes and extensive thin-web areas are possible.
- There are low scrap rates (3 percent).

LIMITATIONS:

CHM does have limitations and areas of disadvantage:

- Only shallow cuts are practical: up to 12.27 mm for sheets and plates,3.83 mm on extrusions, and 6.39 mm on forgings.
- Handling and disposal of chemicals can be troublesome.
- Hand masking, scribing, and stripping can be time-consuming, repetitive, and tedious.
- Surface imperfections are reproduced in the machined parts.
- Metallurgical homogeneous surfaces are required for best results.
- Deep narrow cuts are difficult to produce.
- Fillet radii are fixed by the depth of cut.
- Porous castings yield uneven etched surfaces.
- Welded areas frequently etch at rates that differ from the base metal.
- Material removal from one side of residually stressed material can

result in a considerable distortion.

- The absence of residual stresses on the chemically machined surfaces can produce unfavorable fatigue strength compared with the processes that induce compressive residual stresses.
- Hydrogen pickup and intergranular attack are a problem with some materials.The straightness of the walls is subject to fillet and undercutting limitations.
- Scribing accuracy is limited and complex designs become expensive. Steep tapers are not practical.

APPLICATIONS:

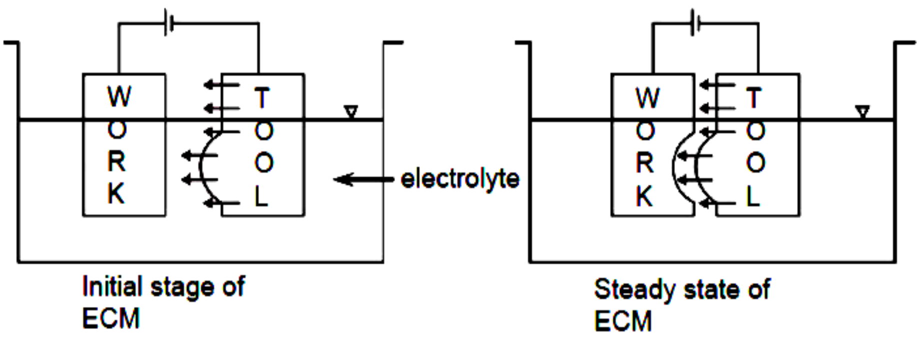
- All the common metals including aluminum, copper, zinc, steel, lead, andnickel can be chemically machined. Many exotic metals such as titanium,molybdenum, and zirconium, as well as nonmetallic materials including glass, ceramics, and some plastics, can also be used with the process.

- CHM applications range from large aluminum airplane wing parts to minute integrated circuit chips. The practical depth of cut ranges between 2.54 to 12.27 mm. Shallow cuts in large thin sheets are of the most popular application especially for weight reduction of aerospace components.

- Multiple designs can be machined from the same sheet at the same time. CHM is used to thin out walls, webs, and ribs of parts that have been produced by forging, casting, or sheet metal forming.

ECM process with neat sketch and also mention theadvantages, limitations and applications.

- Electrochemical Machining (ECM) is a non-traditional machining (NTM) process belonging to Electro chemical category. ECM is opposite of electrochemical or galvanic coating or deposition process. Thus ECM can be thought of a controlled anodic dissolution at atomic level of the work piece that is electrically conductive by a shaped tool due to flow of high current at relatively low potential difference through an electrolyte which is quite often water based neutral salt solution.



Schematic principle of Electro Chemical Machining (ECM)

Principles of electrolysis:

- Electrolysis occurs when an electric current passes between twoelectrodes dipped into an electrolyte solution. The system of the electrodes and the electrolyte is referred to as the electrolytic cell. The chemical reactions, which occur at the electrodes, are called the anodic or cathodic reactions. ED of the anodic workpiece forms the basis for ECM of metals.

- The amount of metal dissolved (removed by machining) or deposited is calculated from Faraday‟s laws of electrolysis, which state that

1. The amount of mass dissolved (removed by machining), m, is directly proportional to the amount of electricity.

$$m \propto It$$

2. The amount of different substances dissolved, m, by the same quantity of electricity (It) is proportional to the substances‟ chemical equivalent weight e.

$$m \propto \epsilon$$

$$\varepsilon = \frac{A}{Z}$$

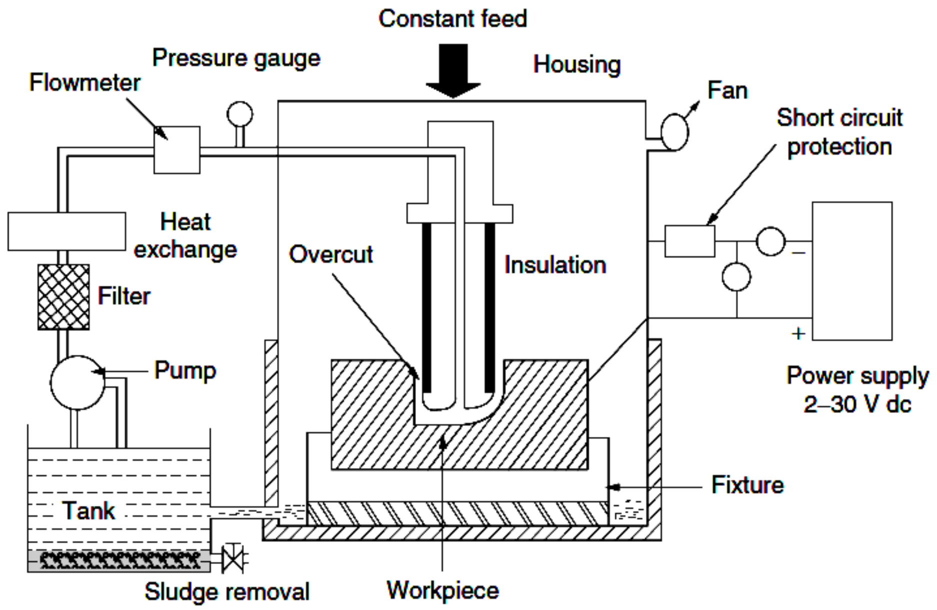
where I = electrolyzing current, A
t = machining time, min
ε = chemical equivalent weight, g
A = atomic weight
Z = workpiece valence

ECM equipment

- Figure shows the main components of the ECM machine: the feed control system, electrolyte supply system, power supply unit, and work piece holding device. As shown in Fig. the feed control system is responsible for feeding the tool at a constant rate during equilibrium machining.

- The power supply drives the machining current at a constant dc (continuous or pulsed) voltage. The electrolyte-feeding unit supplies the electrolyte solution at a given rate, pressure, and temperature.

- Facilities for electrolyte filtration, temperature control, and sludge removal are also included. ECM machines are capable of performing a wide range of operations such as duplicating, sinking, and drilling. Semiautomatic and fully automated facilities are used for large-size machining, such as deburring in the automotive industry. ECM machines, in contrast to conventional machine tools, are designed to stand up to corrosion attack by using nonmetallic materials. For high strength or rigidity, metals with nonmetallic coatings are recommended

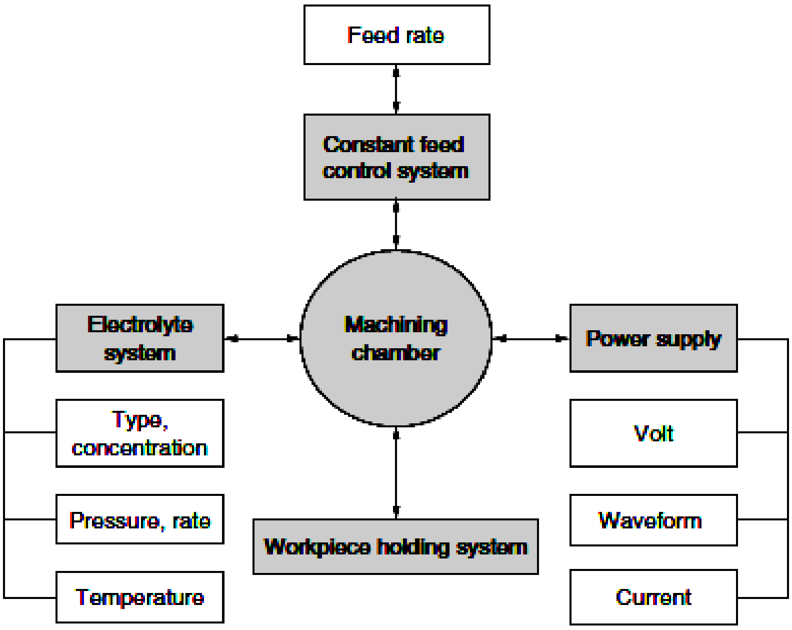


Power supply:

The dc power supply for ECM has the following features:

1. Voltage of 2 to 30 volts (V) (pulsed or continuous)
2. Current ranges from 50 to 10,000 amperes (A), which allow current densities of 5 to 500 A/cm2
3. Continuous adjustment of the gap voltage
4. Control of the machining current in case of emergency
5. Short circuit protection in a matter of 0.001 s
6. High power factor, high efficiency, small size and weight, and low cost Electrolytes.

EDM SYSTEM COMPONENTS:



The main functions of the electrolytes in ECM are to

1. Create conditions for anodic dissolution of work piece material
2. Conduct the machining current
3. Remove the debris of the electrochemical reactions from the gap
4. Carry away the heat generated by the machining process
5. Maintain a constant temperature in the machining region

The electrolyte solution should, therefore, be able to

1. Ensure a uniform and high-speed anodic dissolution
2. Avoid the formation of a passive film on the anodic surface (electrolytes containing anions of Cl, SO4, NO3, ClO3, and OH are often recommended)
3. Not deposit on the cathode surface, so that the cathode shape remains unchanged (potassium and sodium electrolytes are used)
4. Have a high electrical conductivity and low viscosity to reduce the power loss due to electrolyte resistance and heat generation and to ensure good flow conditions in the extremely narrow inter electrode gap
5. Be safe, nontoxic, and less erosive to the machine body
6. Maintain its stable ingredients and pH value, during the machining period
7. Have small variation in its conductivity and viscosity due to temperature rise
8. Be inexpensive and easily available

ADVANTAGES OF ECM:

The components are not subject to either thermal or mechanical stress.

- No tool wear during ECM process.
- Fragile parts can be machined easily as there is no stress involved.
- ECM deburring can debur difficult to access areas of parts.
- High surface finish (up to 25 µm in) can be achieved by ECM process.

- Complex geometrical shapes in high-strength materials particularly in the aerospace industry for the mass production of turbine blades, jet-engine parts and nozzles can be machined repeatedly and accurately.
- Deep holes can be made by this process.

LIMITATIONS OF ECM:

- ECM is not suitable to produce sharp square corners or flat bottoms because of the tendency for the electrolyte to erode away sharp profiles.
- ECM can be applied to most metals but, due to the high equipment costs, is usually used primarily for highly specialised applications.

APPLICATIONS:

- Dies and glass-making molds, turbine and compressor blades for gas-turbine engines, round or non-round holes, passages, cavities and slots in parts. ECM is also used for deburring of gears, hydraulic and fuel-system parts.
- Die sinking • Profiling and contouring • Trepanning • Grinding • Drilling