

CHEMICAL MACHINING (CHM)

Introduction

Chemical machining (CM) is the controlled dissolution of work piece material (etching) by means of a strong chemical reagent (etchant). In CM material is removed from selected areas of work piece by immersing it in a chemical reagents or etchants; such as acids and alkaline solutions. Material is removed by microscopic electrochemical cell action, as occurs in corrosion or chemical dissolution of a metal. This controlled chemical dissolution will simultaneously etch all exposed surfaces even though the penetration rates of the material removal may be only 0.0025–0.1 mm/min. The basic process takes many forms: chemical milling of pockets, contours, overall metal removal, chemical blanking for etching through thin sheets; photochemical machining (pcm) for etching by using of photosensitive resists in microelectronics; chemical or electrochemical polishing where weak chemical reagents are used (sometimes with remote electric assist) for polishing or deburring and chemical jet machining where a single chemically active jet is used. A schematic of chemical machining process is shown in Figure 6.

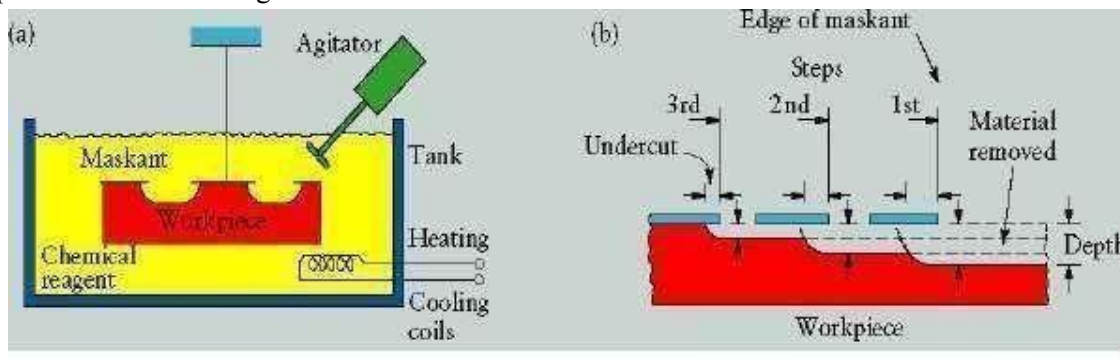


Figure 6: (a) Schematic of chemical machining process (b) Stages in producing a profiled cavity by chemical machining (Kalpakjain & Schmid)

Chemical milling

In chemical milling, shallow cavities are produced on plates, sheets, forgings and extrusions. The two key material used in chemical milling processes are etchant and maskant. Etchants are acid or alkaline solutions maintained within controlled ranges of chemical composition and temperature. Maskants are specially designed elastomeric products that are hand strippable and chemically resistant to the harsh etchants.

Steps in chemical milling

- a) Residual stress relieving: If the part to be machined has residual stresses from the previous processing, these stresses first should be relieved in order to prevent warping after chemical milling.
- b) Preparing: The surfaces are degreased and cleaned thoroughly to ensure both good adhesion of the masking material and the uniform material removal.
- c) Masking: Masking material is applied (coating or protecting areas not to be etched).
- d) Etching: The exposed surfaces are machined chemically with etchants.
- e) Demasking: After machining, the parts should be washed thoroughly to prevent further reactions with or exposure to any etchant residues. Then the rest of the masking material is removed and the part is cleaned and inspected.

Applications:

Chemical milling is used in the aerospace industry to remove shallow layers of material from large aircraft components missile skin panels (Figure 7), extruded parts for airframes.

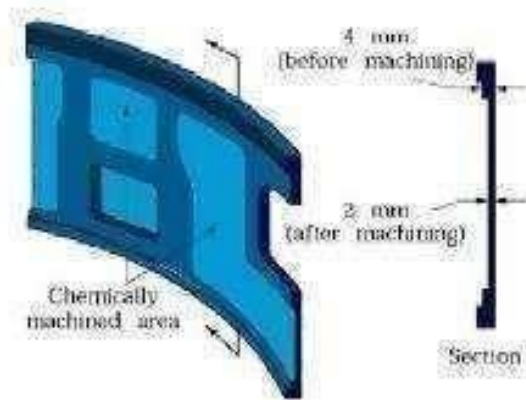


Figure 7: Missile skin-panel section contoured by chemical milling to improve the stiffness- to- weight ratio of the part (Kalpakjain & Schmid)

Electrochemical Machining (ECM) Introduction

Electrochemical machining (ECM) is a metal-removal process based on the principle of reverse electroplating. In this process, particles travel from the anodic material (workpiece) toward the cathodic material (machining tool). A current of electrolyte fluid carries away the depleted material before it has a chance to reach the machining tool. The cavity produced is the female mating image of the tool shape.

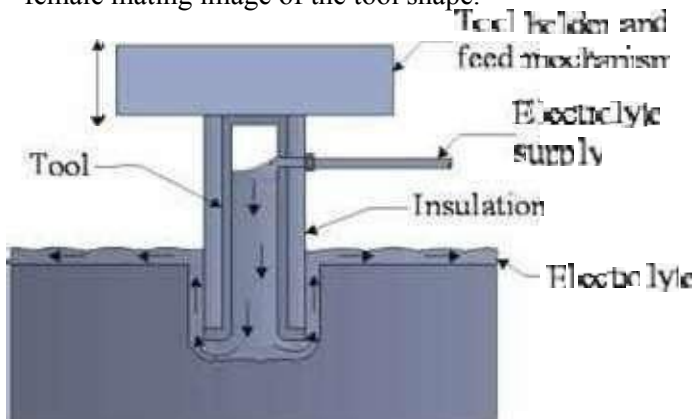


Figure 8: ECM process

Similar to EDM, the workpiece hardness is not a factor, making ECM suitable for machining difficult-to-machine materials. Difficult shapes can be made by this process on materials regardless of their hardness. A schematic representation of ECM process is shown in Figure 8. The ECM tool is positioned very close to the workpiece and a low voltage, high amperage DC current is passed between the workpiece and electrode. Some of the shapes made by ECM process is shown in Figure9.



Figure 9: Parts made by ECM

Advantages of ECM

- a) The components are not subject to either thermal or mechanical stress.
- b) No tool wear during ECM process.
- c) Fragile parts can be machined easily as there is no stress involved.
- d) ECM deburring can debur difficult to access areas of parts.
- e) High surface finish (up to $25\text{ }\mu\text{m}$ in) can be achieved by ECM process.
- f) 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.
- g) Deep holes can be made by this process.

Limitations of ECM

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

Material removal rate, MRR, in ECM $MRR = C.I.h$ (cm^3/min)

C: specific (material) removal rate (e.g., $0.2052\text{cm}^3/\text{amp-min}$ for nickel); I:

current (amp);

h: current efficiency (90–100%).

The rates at which metal can electrochemically remove are in proportion to the current passed through the electrolyte and the elapsed time for that operation. Many factors other than current influence the rate of machining. These involve electrolyte type, rate of electrolyte flow, and some other process conditions.

ELECTROCHEMICAL HONING

Electrochemical honing is one of the non-equilibrium gap processes in ECM and is a new technique, which in spite of being used in some industrial plants especially to smooth surfaces, is still not fully described due to the variety of the factors affecting the process. More information about the process is required especially the effects of the working parameters on the produced surface roughness. A special honing tool was designed by using different tool tip shapes (rectangular, circular, triangle & inclined) to study the ability for improving the surface roughness. This work presents a study for the factors affecting the electrochemical honing process especially the machining time, workpiece material, initial working gap, tool rotational speed, tool tip shape and the inclined tool tip angle. The results are finally furnished with the aim to generalize a useful guideline for the user to enable proper selection of conditions for obtaining good surface quality.

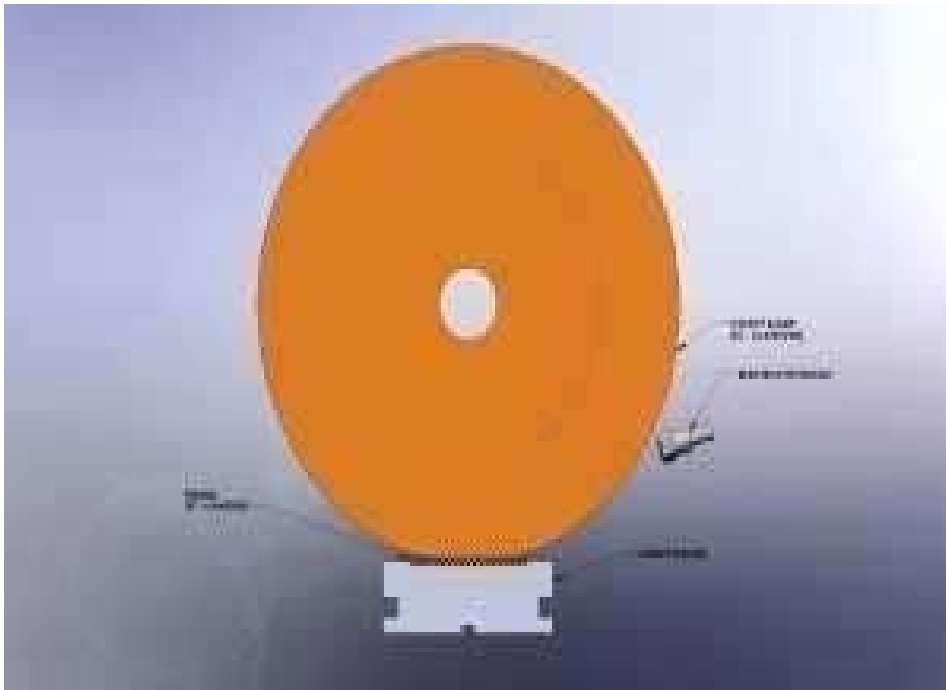
Electrochemical Grinding Process Overview

Electrochemical Grinding (ECG) Process Overview

Electrochemical Grinding, or ECG, is a variation of ECM (Electrochemical Machining) that combines electrolytic activity with the physical removal of material by means of charged grinding wheels. Electrochemical Grinding (ECG) can produce burr free and stress free parts without heat or other metallurgical damage caused by mechanical grinding, eliminating the need for secondary machining operations. Like ECM, Electrochemical Grinding (ECG) generates little or no heat that can distort delicate components.

Electrochemical Grinding (ECG) can process any conductive material that is electrochemically reactive. The most common reason customers choose ELECTROCHEMICAL GRINDING (ECG) is for the burr free quality of the cut. If a part is difficult or costly to deburr, then ELECTROCHEMICAL GRINDING (ECG) is the best option. Materials that are difficult to machine by conventional methods, that work harden easily or are subject to heat damage are also good candidates for the stress free and no heat characteristics of ELECTROCHEMICAL GRINDING (ECG). The stress free cutting capability of the process also make it ideal for thin wall and delicate parts.

The real value of Electrochemical Grinding (ECG) is in metal working applications that are too difficult or time-consuming for traditional mechanical methods (milling, turning, grinding, deburring etc.). It is also effective when compared to non-traditional machining processes such as wire and sinker EDM. ELECTROCHEMICAL GRINDING (ECG) is almost always more cost effective than EDM.



ELECTROCHEMICAL GRINDING (ECG) differ from conventional grinding
Conventional surface grinding typically uses shallow reciprocating cuts that sweep across the work surface to create a flat plane or groove. Another conventional surface grinding process, creep feed grinding, typically uses slower feeds than conventional surface grinding and removes material in deep cuts. Because of the abrasive nature of these processes, the equipment used must be rigid and this is especially true of creep feed grinding.

Quality ELECTROCHEMICAL GRINDING (ECG) machines must also be rigid for close tolerance results but since very little of the material removed is done so abrasively the machines do not have to be as massive as their conventional counterparts. To a user familiar with creep feed grinding ELECTROCHEMICAL GRINDING (ECG) will appear to be very similar, that is, relatively slow feeds (as compared to conventional surface grinding) and deep cuts as opposed to shallow reciprocating cuts. ELECTROCHEMICAL GRINDING (ECG) is a combination of electrochemical (Anodic) dissolution of a material, according to Faraday's Law, and

light abrasive action. The metal is decomposed to some degree by the DC current flow between the conductive grinding wheel (Cathode) and the work piece (Anode) in the presence of an electrolyte solution.

Unlike conventional grinding techniques, ELECTROCHEMICAL GRINDING (ECG) offers the ability to machine difficult materials independent of their hardness or strength. ELECTROCHEMICAL GRINDING (ECG) does not rely solely on an abrasive process; the results are precise burr free and stress free cuts with no heat and mechanical distortions.



ELECTROCHEMICAL GRINDING (ECG) compare to EDM, laser, water- jet and other non-traditional technologies

EDM and laser both cut metal by vaporizing the material at very high temperatures. This results in a re-cast layer and a heat affected zone on the material surface. ELECTROCHEMICAL GRINDING (ECG) is a no heat process that never causes metallurgical damage. ELECTROCHEMICAL GRINDING (ECG) is usually much faster than EDM but typically is less accurate. Laser cutting can be very fast and accurate but it is normally limited to thin materials. Water-jet cutting can be quite fast and usually leaves no metallurgical damage but the consumable costs can be very high and the cuts are limited to jigsaw type cuts much like Wire EDM. In most cases, ELECTROCHEMICAL GRINDING (ECG) is a more accurate process than water-jet. Another difference between water jet and laser machining compared to ELECTROCHEMICAL GRINDING (ECG) is laser and water jet can both process materials that are not conductive. EDM and ELECTROCHEMICAL GRINDING (ECG) processes can only work on materials that are conductive.

Tolerances can be achieved with ELECTROCHEMICAL GRINDING (ECG) The tolerances that can be achieved using ELECTROCHEMICAL GRINDING (ECG) depend greatly on the material being cut, the size and depth of cut and ECG parameters being used. On small cuts, tolerances of .0002" (.005mm) can be achieved with careful control of the grinding parameters.

Surface finishes can be achieved with ELECTROCHEMICAL GRINDING (ECG) The ELECTROCHEMICAL GRINDING (ECG) process does not leave the typical shiny finish of abrasive grinding. This is because there is no smearing of the metal as in conventional grinding. A 16 micro inch finish or better can be achieved but it will have a matte (dull) rather than a polished look.

Materials can be cut with ELECTROCHEMICAL GRINDING (ECG). Almost any conductive metal can cut with ELECTROCHEMICAL GRINDING (ECG). Steel, Aluminum, Copper, Stainless Steels, Inconel and Hastelloy cut very freely with ELECTROCHEMICAL GRINDING (ECG). Nickel/Titanium, Cobalt alloys, Amorphous metals, Berilium, Berilium Copper, Iridium Neodymium Iron/Boron, Titanium, Nickel/Titanium, Nitinol, Powdered Metals, Rene41, Rhenium, Rhodium, Vitalium, Zirconium and Tungsten can also be cut effectively.

ADVANTAGES OF ELECTROCHEMICAL GRINDING (ECG)

- a) Improved wheel life
- b) Burr free
- c) No work hardening
- d) Stress free
- e) Better finish
- f) No cracking
- g) Less frequent wheel dressing
- h) No metallurgical damage from heat
- i) Faster for tough materials
- j) No wheel loading or glazing
- k) More precise tolerances