Modern Manufacturing Processes

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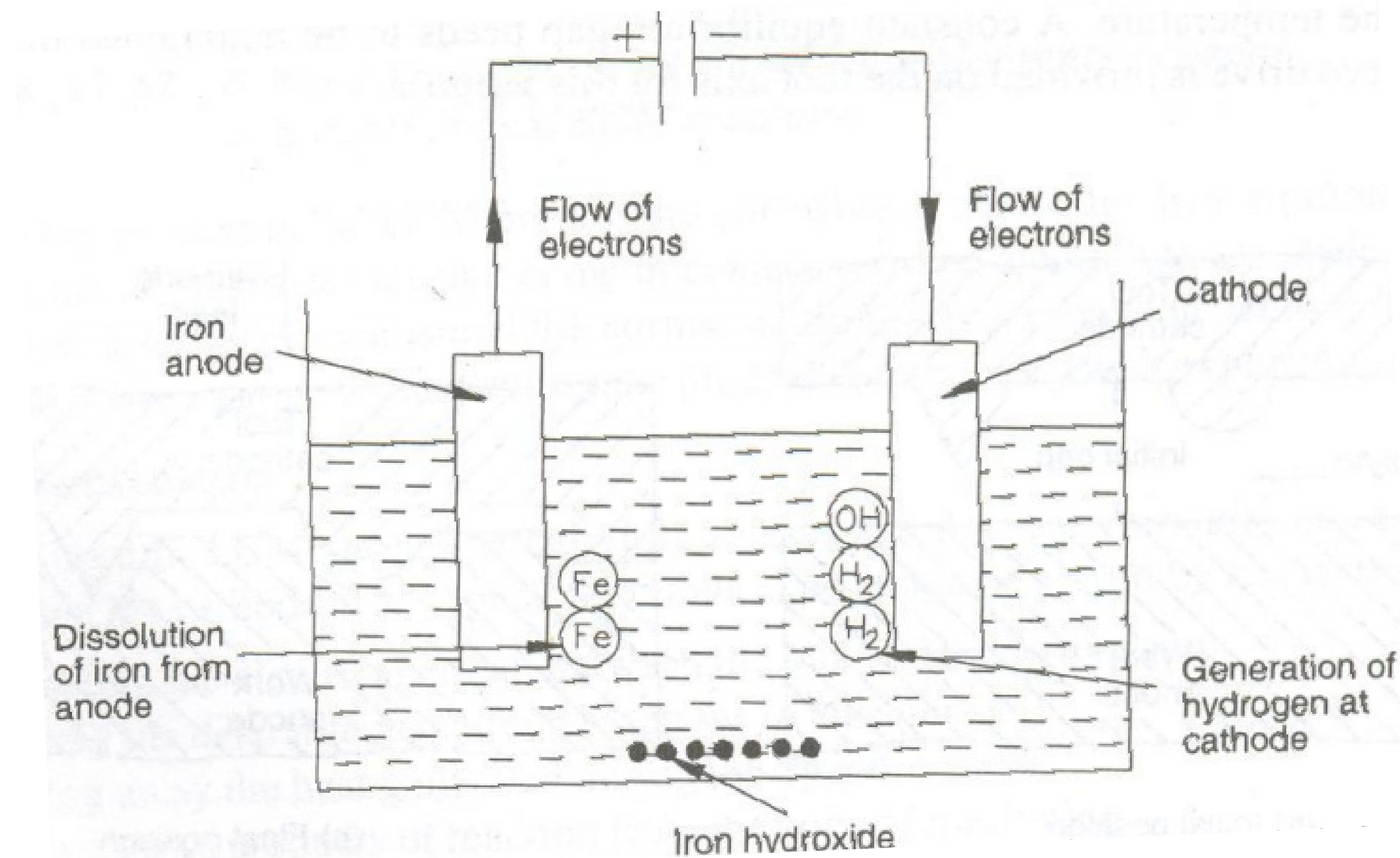
OUR CONCERN

Unit I:	**Introduction and Electro Discharge Machining (EDM)**
Unit II:	**Electro Chemical Machining (ECM), Electron Beam Machining (EBM), Electron Beam Welding (EBW), and Laser beam Welding (LBW)**
Unit III:	**Ultrasonic Machining (USM), Abrasive Jet Machining (AJM), Water Jet Machining (WJM)**
Unit IV:	**Chemical Machining (CHM), Comparison of Unconventional Machining Processes**

Electrochemical Machining (E.C.M.)

- Electrochemical machining (ECM) is an electrolytic material removal process involving a negatively charged shaped electrode (cathode), a conductive fluid (electrolyte), and a conductive workpiece (anode).

- ECM is an electrolytic process and its basis is the phenomenon of electrolysis, whose laws were established by Faraday in 1833.



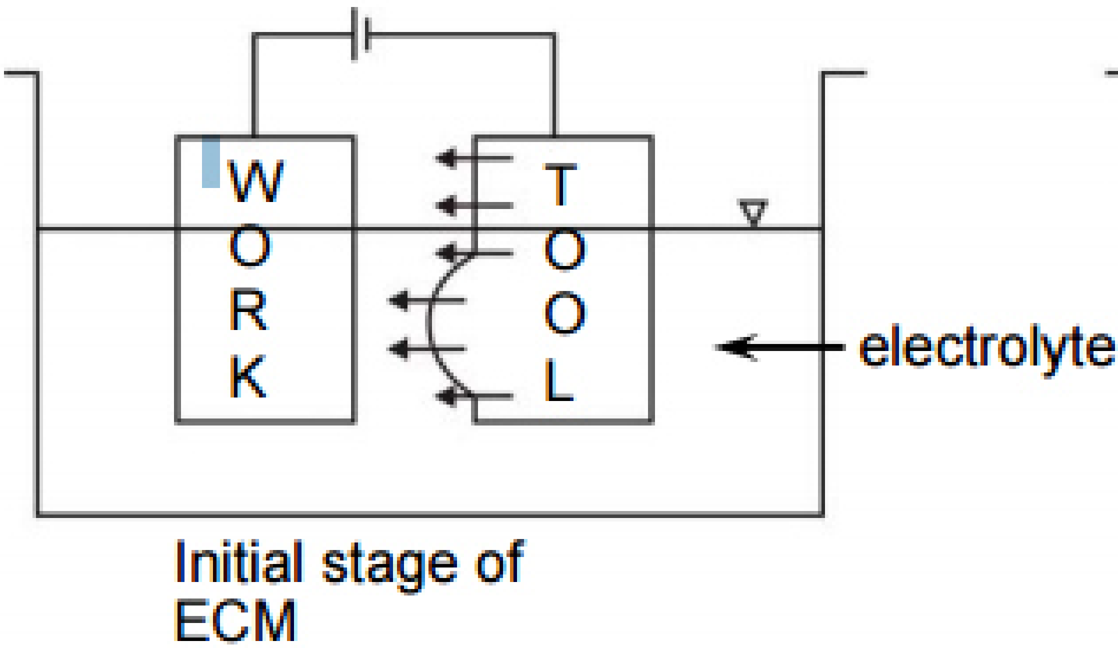
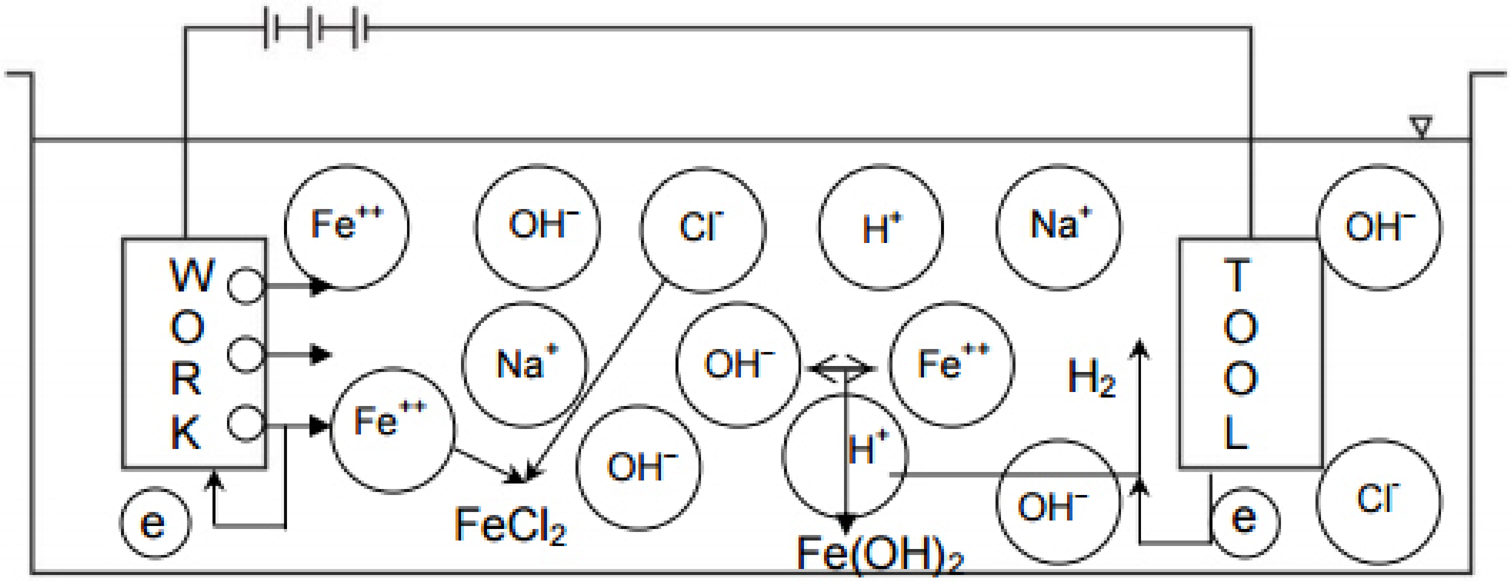


Fig. 1 Schematic principle of Electro Chemical Machining (ECM)



Anode: $Fe \Rightarrow Fe^{+2} + 2e^{-1}$

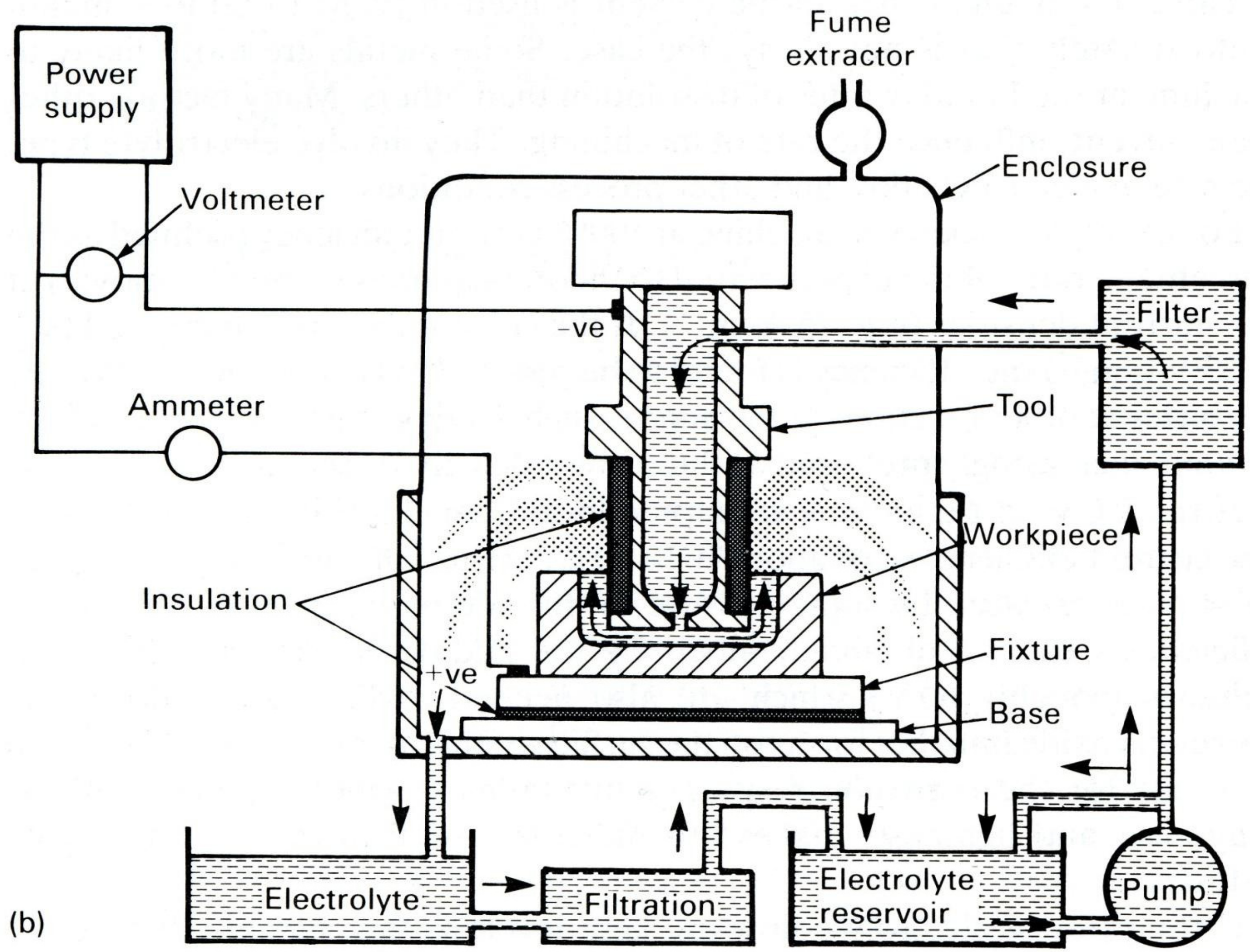
Cathode: $H_2O \Rightarrow H^{+} + OH^{-}$

Electrolyte: $NaCl \Rightarrow Na^{+} + Cl^{-}$

$Fe^{+2} + 4Cl^{-} \Rightarrow 2FeCl_2$

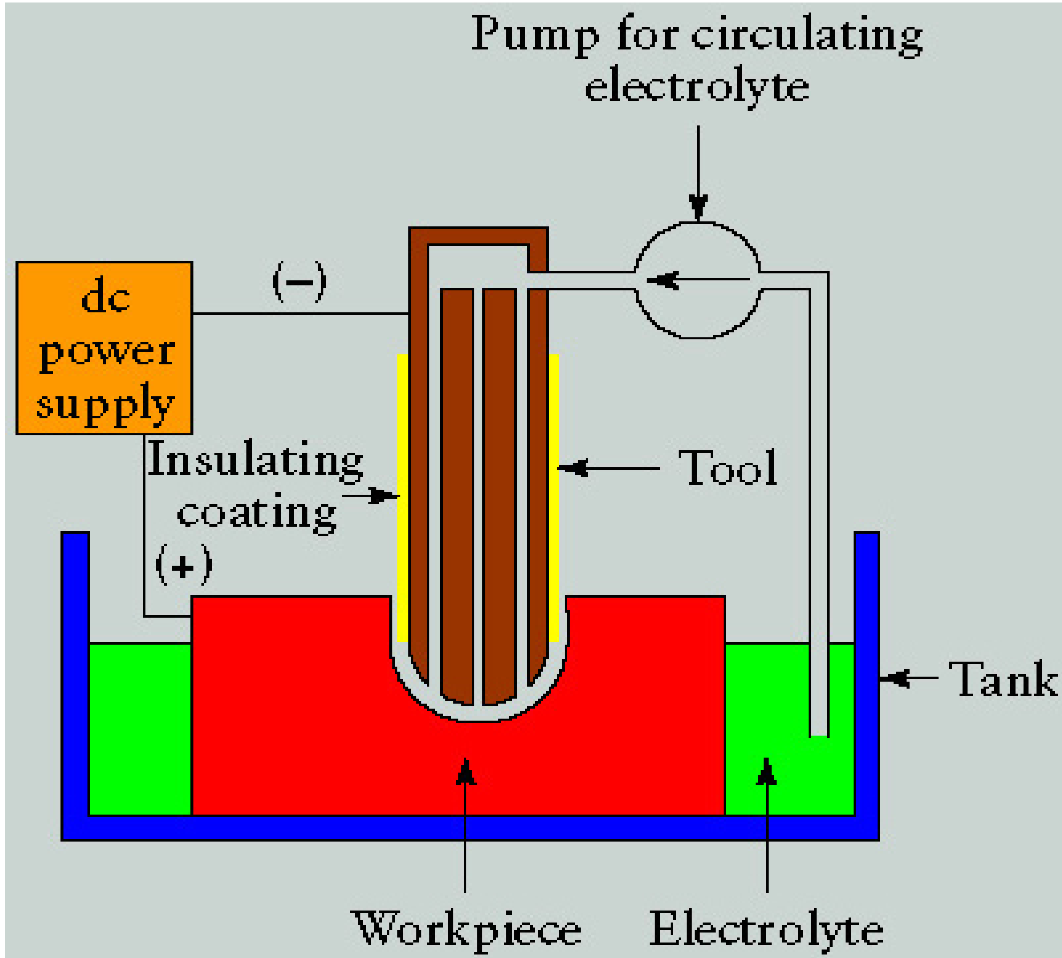
$Fe^{+2} + 4OH^{-} \Rightarrow 2Fe(OH)_2$

$Na^{+} + OH^{-} \Rightarrow NaOH$


Fume extractor
Power supply
Voltmeter
Enclosure
-ve
Filter
Tool
Ammeter
Workpiece
Insulation
Fixture
+ve
Base
Electrolyte
Filtration
Electrolyte reservoir
Pump
(b)

Electrochemical Machining (E.C.M.)(cont..)

In the ECM process, the dc power source charges the workpiece positively and charges the tool negatively. As the machine slowly brings the tool and workpiece close together, perhaps to within 0.010 of an inch, the power and electrolyte flow are turned on. Electrons flow across the narrow gap from negative to positive, dissolving the workpiece into the shape as the tool advances into it. The recirculating electrolytic fluid carries away the dissolved material as a metal hydroxide.



Electrochemical Machining (E.C.M.)(cont..)

•In ECM one employs a cathode electrode shaped to provide the complementary structure in an anode work piece.

•A highly conductive electrolyte stream separates the cutting tool from the work piece, and metal removal is accomplished by passing a dc current of up to $100 A/cm^2$ through the salt solution cell. As the cathode tool approaches the anode work piece it erodes its complementary shape in it.

•Thus complex shapes may be made from a material such as soft copper and used to produce negative duplicates of it. The process is also called electrochemical sinking.

https://www.youtube.com/watch?v=Ej-GWNPYFVM

https://www.youtube.com/watch?v=ARa983c0XTs

Electrochemical Machining (E.C.M.)(cont..)

Material Removal Rate (MRR):

According to Faraday's first law of electrolysis, mass of ion liberated by the substance,

$$M = ZIt$$

Where, I = current flowing through the electrolytic cell

t= time in sec

Z=ECE= constant known as the electro- chemical equivalent of the substance.

Material removal rate (MRR) in ECM: material removal takes place due to atomic dissolution of work material, governed by Faraday's laws.

The first law of Faraday states that the amount of electrochemical dissolution or deposition is proportional to amount of charge passed through the electrochemical cell, which is expressed as:

$$m \propto Q,$$

where m = mass of material dissolved or deposited , Q = amount of charge passed

The second law states that the amount of material deposited or dissolved further depends on Electrochemical Equivalence (ECE) of the material that is again the ratio atomic weight and valancy. Here A=M

$$m \; \alpha \; ECE \; \alpha \; \frac{A}{\nu}$$

$$\text{Thus } m \; \alpha \; \frac{QA}{\nu}$$

where F = Faraday's constant
= 96500 coulombs

$$\therefore \quad m = \frac{ItA}{F\nu}$$

Now,

$$MRR = \frac{\text{Volume removed}}{\text{Time taken}} = \frac{m/\rho}{t} = \frac{m}{\rho t}$$

$$\Rightarrow MRR = \frac{\left(\frac{ItM}{Fv}\right)}{\rho t} = \frac{IM}{F\rho v}$$

$$\Rightarrow MRR = \frac{IM}{F\rho v}$$

where, I = current, ρ = density

Let us assume there are 'n' elements in an alloy. The atomic weights are given as M_i ($M_1, M_2, \ldots M_n$) with valency during electrochemical dissolution as v_i ($v_1, v_2, \ldots v_n$). The weight percentages of different elements are x_i ($x_1, x_2, \ldots x_n$).

Now for passing a current of I for a time t, the mass of material dissolved for any element 'i' is given by

$$m_i = \frac{V_a \rho x_i}{100}$$

where V_a is the total volume of alloy dissolved. Each element present in the alloy takes a certain amount of charge to dissolve.

$$m_i = \frac{Q_i M_i}{F \nu_i}$$

$$\Rightarrow Q_i = \frac{F \nu_i m_i}{M_i}$$

$$\Rightarrow Q_i = \frac{F \nu_i \left(V_a \rho x_i / 100 \right)}{M_i}$$

$$\Rightarrow Q_i = \frac{F V_a \rho x_i \nu_i}{100 M_i}$$

The total charge (Q_T) passed is the algebraic sum of charge passed of individual elements in the alloy. So, we can write,

$$Q_T = It = \sum_{i=1}^{n} Q_i$$

$$\Rightarrow Q_T = It = \sum_{i=1}^{n} \frac{F V_a \rho x_i \nu_i}{100 M_i} = V_a \rho F \sum_{i=1}^{n} \frac{x_i \nu_i}{100 M_i}$$

$$\Rightarrow It = V_a \rho F \sum_{i=1}^{n} \frac{x_i \nu_i}{100 M_i}$$

$$\Rightarrow V_a = \frac{It}{\rho F \sum_{i=1}^{n} \frac{x_i \nu_i}{100 M_i}}$$

$$\text{Now, } MRR = \frac{\text{Total volume Dissolved}}{\text{Total time}} = \frac{V_a}{t}$$

$$\Rightarrow MRR = \frac{V_a}{t} = \frac{\frac{It}{F \rho \sum_{i=1}^{n} \frac{x_i \nu_i}{100 M_i}}}{t} = \frac{I}{\rho F \sum_{i=1}^{n} \frac{x_i \nu_i}{100 M_i}}$$

Thus, Volumetric Material Removal Rate (MRR) for an alloy with 'n' elements by Electrochemical Machining is given by:

$$\text{MRR} = \frac{100}{\rho F} \frac{I}{\sum_{i=1}^{n} \frac{x_i \nu_i}{M_i}}$$

Principle:

•Based on the principle of Faraday's law of electrolysis.

Characteristic:

- Small gap between tool and work-piece (≈ 0.5mm).
- Wok-piece stationary, feed by tool.
- Electrolyte: Aqueous solution of common salt, dilute acid.
- Pressure of electrolyte ≈ 14 kg/cm2
- Velocity of electrolyte = 30 to 60 m/sec.
- Temperature of electrolyte = 25 to60°C .
- Voltage of electrolyte = 5 to 15V

ECM: Advantages

•Components are not subject to either thermal or mechanical stress.

•There is no tool wear in ECM.

•Non-rigid and open work pieces can be machined easily as there is no contact between the tool and work piece.

•Complex geometrical shapes can be machined repeatedly and accurately.

•ECM is a time saving process when compared with conventional machining

•During drilling, deep holes can be made or several holes at once.

•Fragile parts which cannot take more loads and also brittle material which tend to develop cracks during machining can be machined easily in ECM

•Surface finishes of 25 μ in. can be achieved in ECM

ECM: Disadvantages

- Keeping the solution conductivity constant.
- More expensive than conventional machining.
- Need more area for installation.
- Electrolytes may destroy the equipment.
- Not environmentally friendly (sludge and other waste)
- High energy consumption.
- Chemical attack by electrolytes.
- The danger of a burn in the case of a short circuit between the positive and negative leads.
- The danger of a fire damp explosion.
- Material has to be electrically conductive

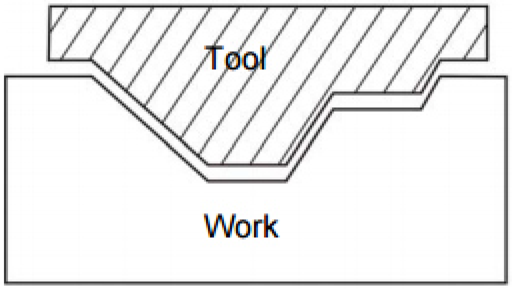
ECM Applications

•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.
• It is also used to make cavities and holes in various products.
• It is commonly used on thin walled, easily deformable and brittle material because they would probably develop cracks with conventional machining.

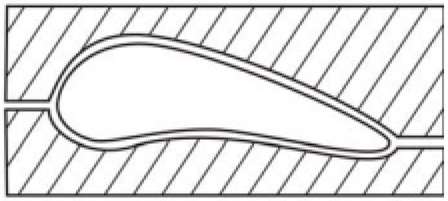
Products

•The two most common products of ECM are turbine/compressor blades and rifle barrels. Each of those parts require machining of extremely hard metals with certain mechanical specifications
•Some of these mechanical characteristics achieved by ECM are:

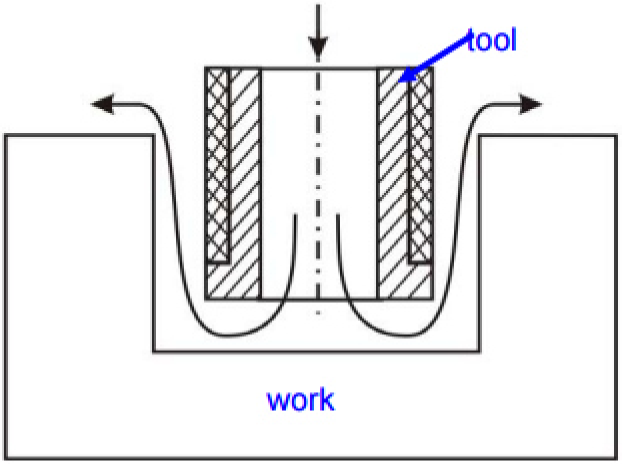
*Stress free grooves.
*Any groove geometry.
*Any conductive metal can be machined.
*Repeatable accuracy of 0.0005”.
*High surface finish.
*Fast cycle time.



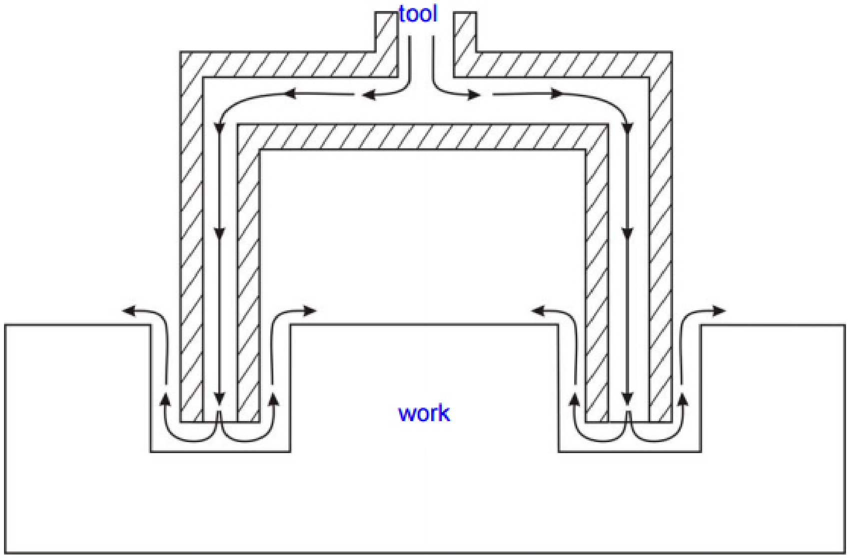
Die sinking



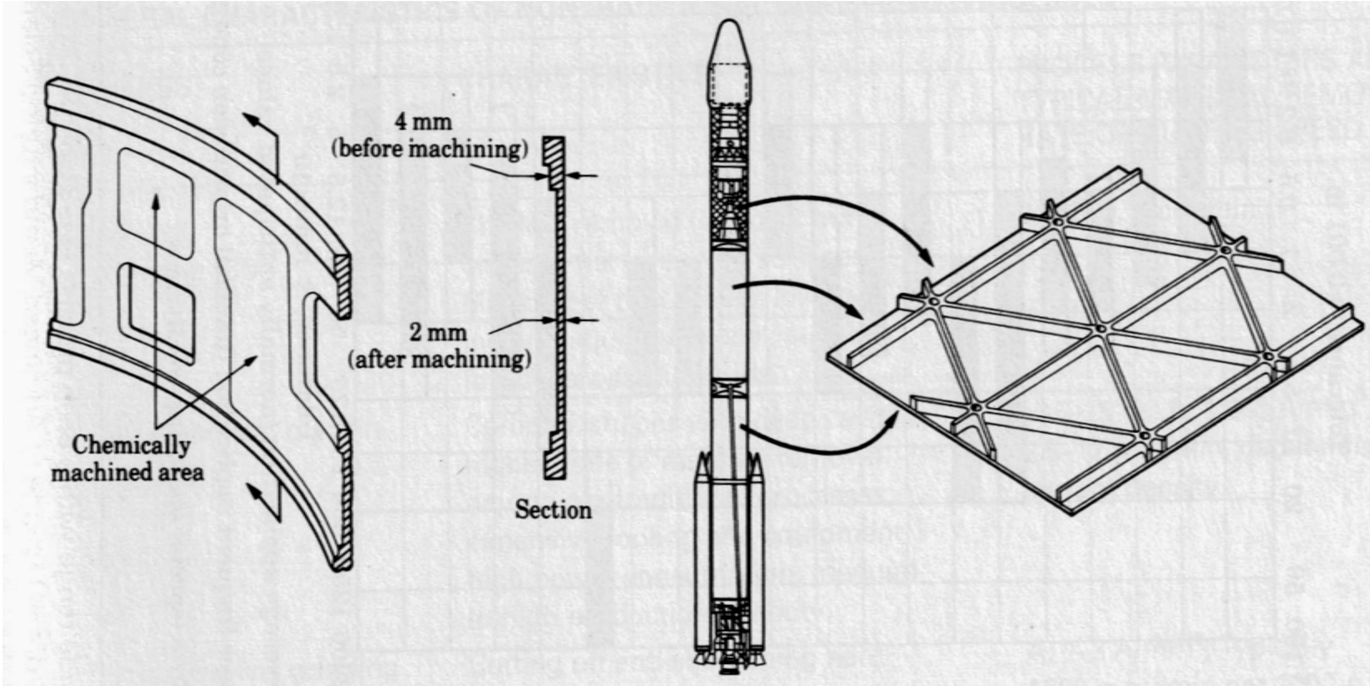
3D profiling



(drilling)



trepanning


4 mm
(before machining)
2 mm
(after machining)
Chemically
machined area
Section

Function of Electrolyte in ECM:

- Completes the electric circuit between tool and work piece.
- Allows desirable machining to occur.
- Carries away products of reaction from the zone of machining.
- Carries away heat generated during chemical reactions.

Properties of Electrolyte For ECM:

- High electrical conductivity.
- Chemical stability.
- High specific heat and low viscosity.