Lecture #37

ERDM

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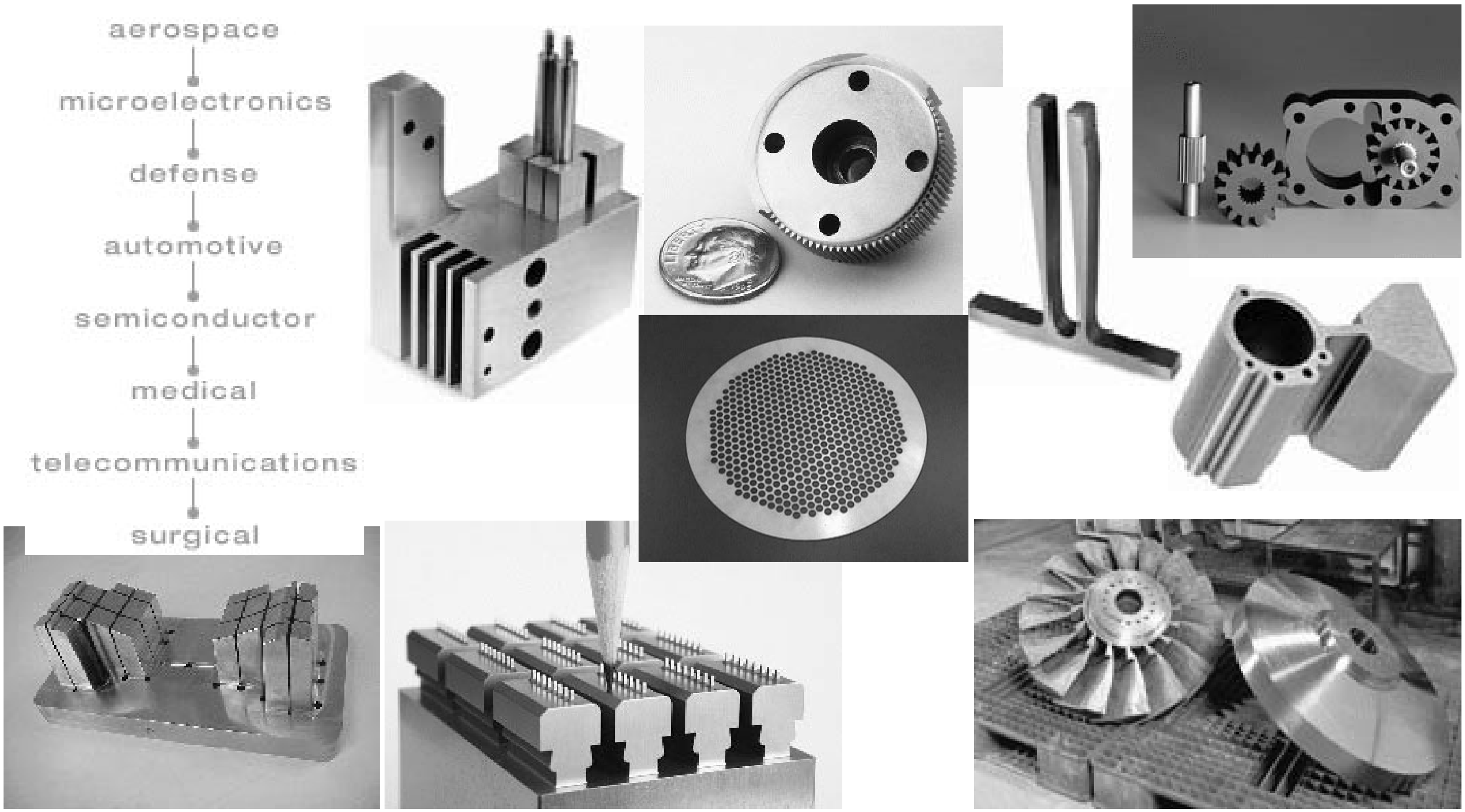
Nontraditional Machining

- **Nontraditional/ Unconventional machining:**
  Material removal techniques using chemical, electrical, thermal and other means (no mechanical force).

  Significant economic and technical advantages, in cases where:
- **Hard, strong base material**
- **Base material too flexible/ slender to cut or clamp**
- **Part geometry is complex**
- **Very high surface finish/ tolerances are required**
- **Temperature rise or residual stresses are undesirable**

Nontraditional Machining Applications:



Nontraditional Machining Processes

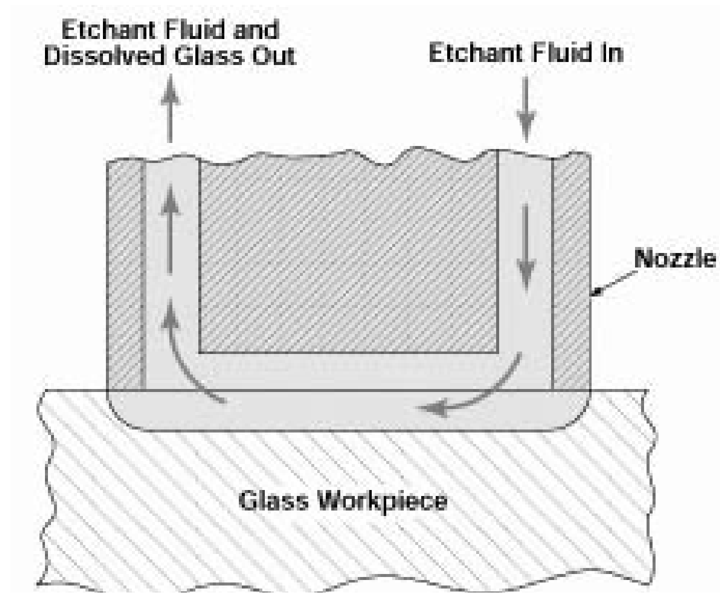
- Chemical Machining (CM)
- Electrochemical Machining (ECM)
- Electrochemical Grinding (ECG)
- Electrical-discharge Machining (EDM)
- Wire EDM
- Laser-beam Machining (LBM)
- Electro-beam Machining (EBM)
- Water-jet Machining (WJM)
- Abrasive Water-jet Machining (AWJM)
- Abrasive Jet Machining (AJM)
- Ultrasonic Machining (USM)

Chemical Machining

Material removal from the surface by controlled chemical dissolution using reagents, etchants - acids/ alkalis

- Chemical milling
- Chemical blanking
- Photochemical blanking

NASA's Jet Propulsion Laboratory
Used to make precise, microscopic holes and grooves

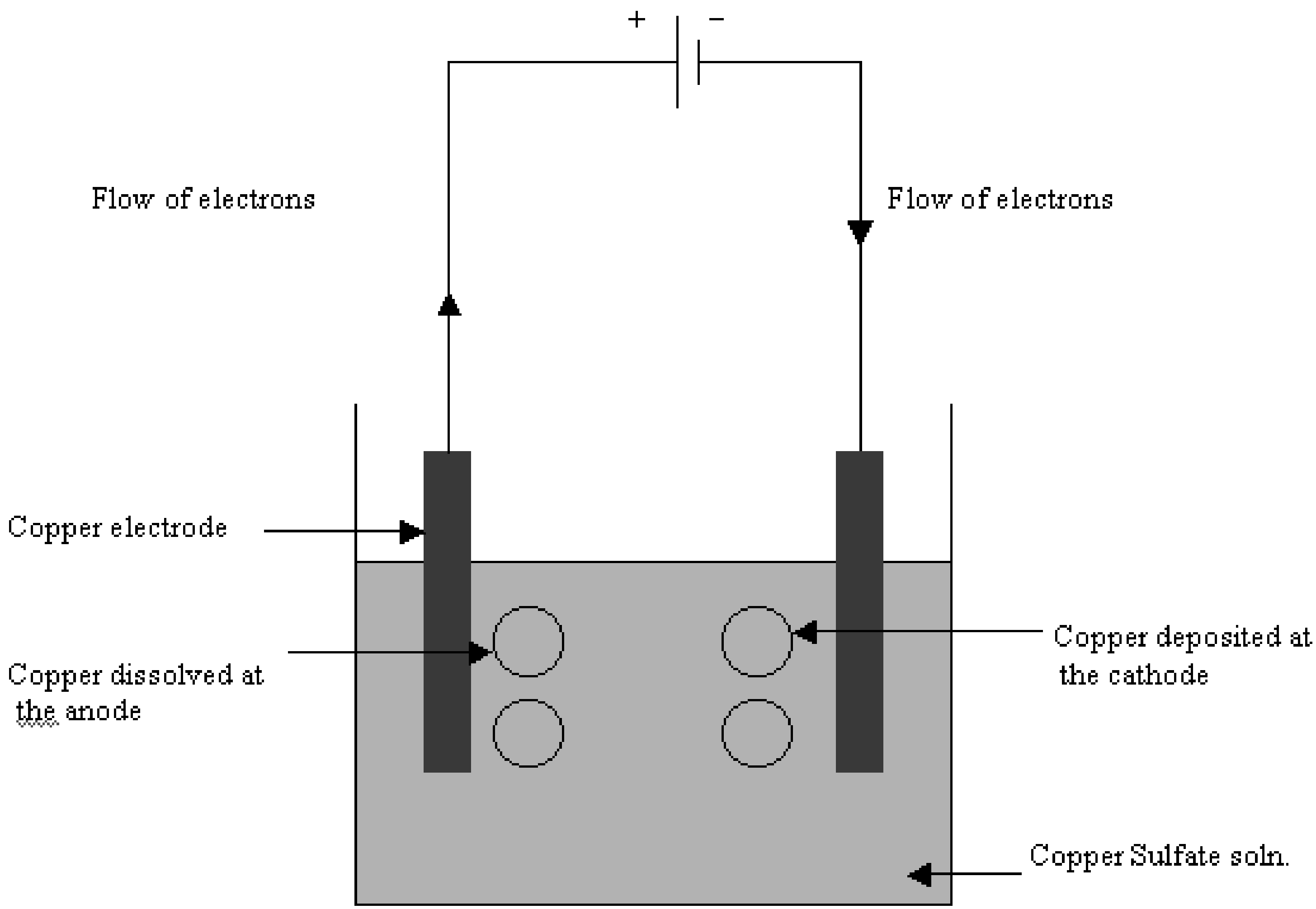


Electrochemical Machining

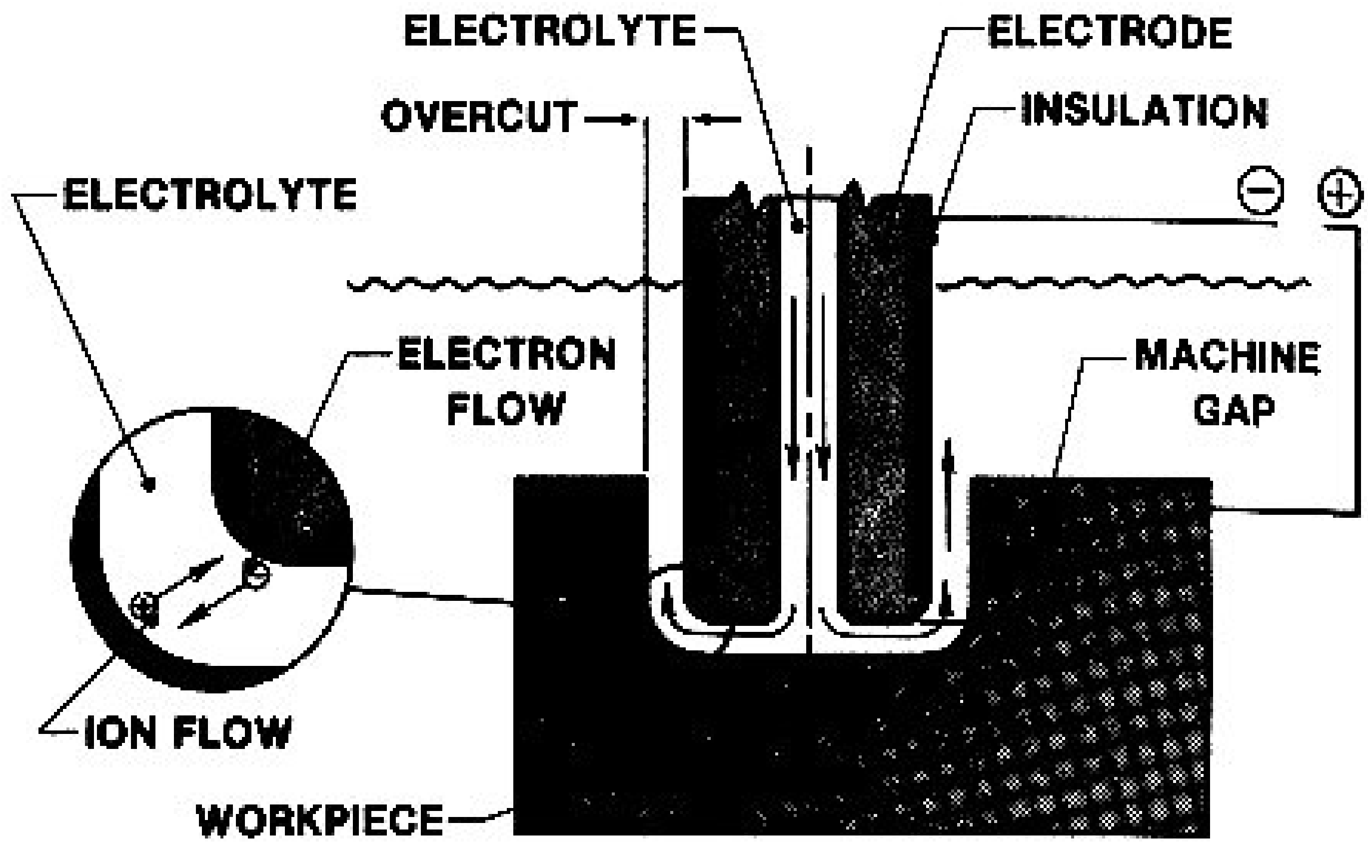
- **Ion exchange is the metal removal mechanism.**
  - **Reverse electroplating**
  - **Workpiece must be electrically conductive**
  - **Electrolyte acts as a current carrier**
  - **High rate of electrolyte movement; washes metal ions.**
  - **The energy consumption of ECM is relatively high, from 200 J/mm^3 to 600 J/mm^3.**

    [Cutting - < 10 J/mm^3]

ECM for the production of gas turbine compressor blades


+
−
Flow of electrons
Flow of electrons
Copper electrode
Copper deposited at
the cathode
Copper dissolved at
the anode
Copper Sulfate soln.

ELECTROCHEMICAL MACHINING



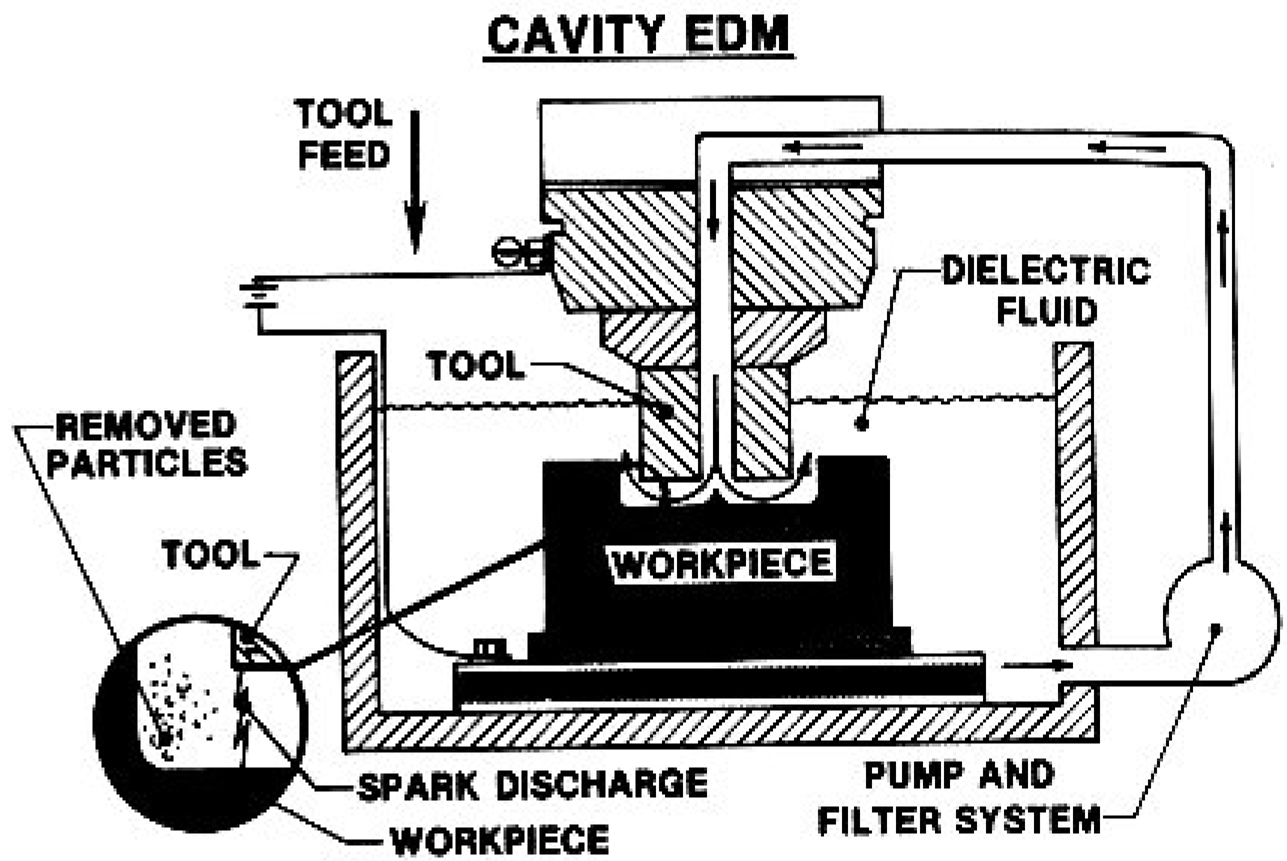
Electrocheical Grinding

Combination of electrochemical machining and conventional grinding

- Majority of the metal removal is by electrolytic action
- Workpiece and grinding wheel must be conductive
- Grinds delicate parts and thin-walled sections without distortion or heat damage
- Electro-chemical oxidation produces a soft hydroxide film on the workpiece surface. The grinding wheel then "wipes away" this hydroxide film.

Electrical-Discharge Machining

- Material vaporized by application of high potential diff. across the workpiece and the tool.
- Spark discharges erode the conducting metal
- Control - Freq. of discharge & energy/ discharge
- Dielectric medium surrounds the workpiece
- Electrodes as small as 0.1 mm dia.
- Widely accepted production technology - 2% of worldwide machining
- Used in combination with other processes like milling, grinding, ultrasonic machining, etc.


CAVITY EDM
TOOL FEED
DIELECTRIC FLUID
TOOL
REMOVED PARTICLES
TOOL
WORKPIECE
SPARK DISCHARGE
WORKPIECE
PUMP AND FILTER SYSTEM

Ultrasonic Machining

Ultrasound - above 20 kHz, can be generated using peizoelectric or magnetostictive effects

- **A formed tool, with the shape of the cavity to be machined is made to vibrate against the workpiece surface and between the two are placed abrasive particles.**
- **The material is removed in the form of grains by shear deformation, brittle fracture of work material; and by impact, cavitation and chemical reaction**

Laser Beam Machining

- Highly focused optical energy of LASER is used to melt & evaporate workpiece portions in a controlled manner
- Reflectivity and thermal conductivity of workpiece are important
- Various applications - Cutting, Drilling, Marking, Surface Treatment, Welding
- Widely used in automotive and electronics industries due to its accuracy, reproducibility, flexibility, ease of automation.

Water-Jet Machining

- **Forces an accelerated water stream to impinge on the workpiece, causing crack initiation and propagation**
- **Can be used with abrasive slurry or abrasive suspension**
- **No heat affected zones**
- **Applications: Printed Circuit Boards, Wire Stripping, Food Preparation,Tool Steel & Wood Cutting and Cleaning.**

Comparison

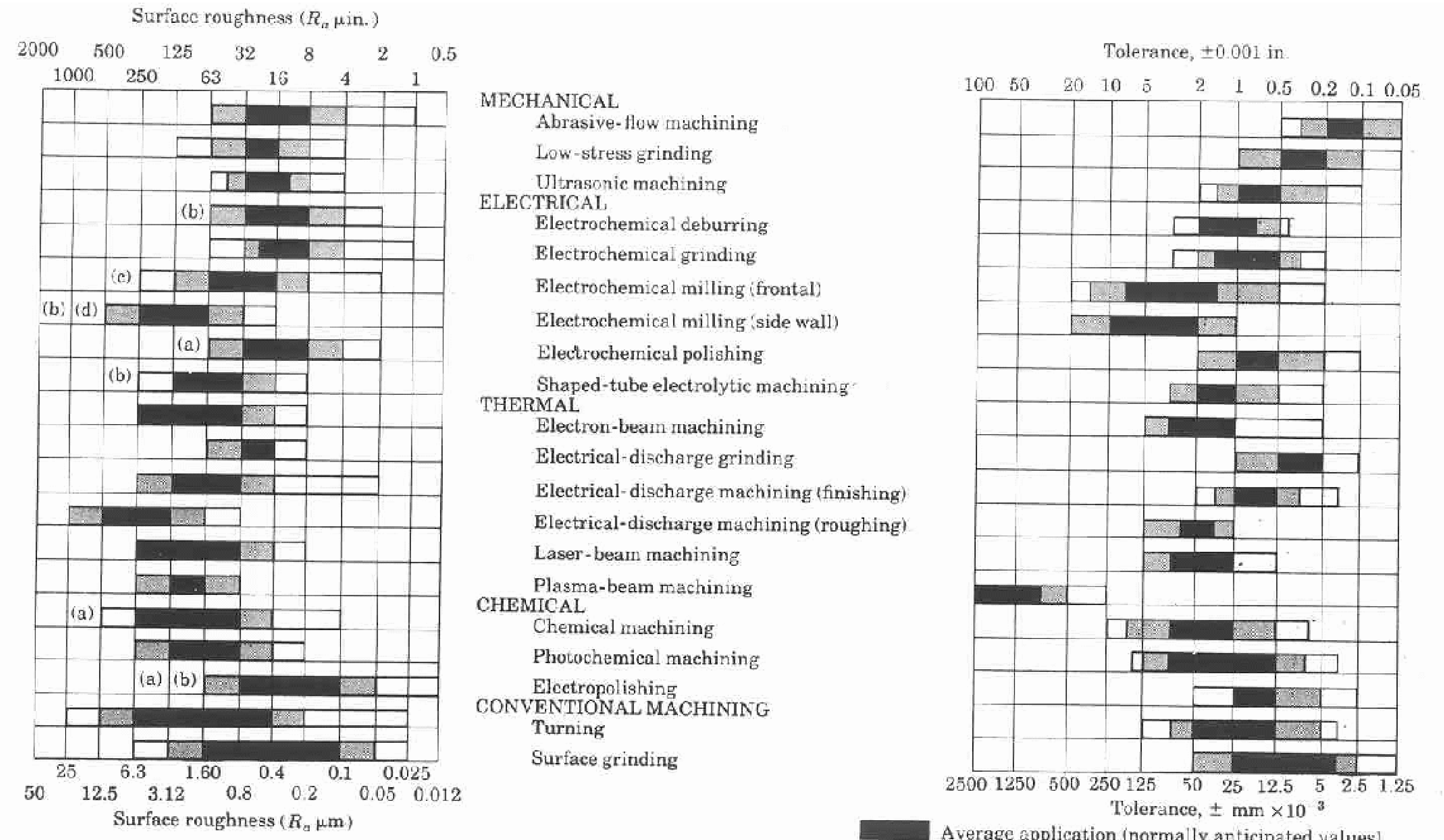
GENERAL CHARACTERISTICS OF NONTRADITIONAL MACHINING PROCESSES

PROCESS	CHARACTERISTICS	PROCESS PARAMETERS AND TYPICAL MATERIAL REMOVAL RATE OR CUTTING SPEED
Chemical machining (CM)	Shallow removal (up to 12 mm) on large flat or curved surfaces; blanking of thin sheets; low tooling and equipment cost; suitable for low production runs.	0.025–0.1 mm/min.
Electrochemical machining (ECM)	Complex shapes with deep cavities; highest rate of material removal among nontraditional processes; expensive tooling and equipment; high power consumption; medium to high production quantity.	V: 5–25 dc; A: 1.5–8 A/mm^2; 2.5–12 mm/min, depending on current density.
Electrochemical grinding (ECG)	Cutting off and sharpening hard materials, such as tungsten-carbide tools; also used as a honing process; higher removal rate than grinding	A: 1–3 A/mm^2; Typically 1500 mm^3/min per 1000 A.
Electrical-discharge machining (EDM)	Shaping and cutting complex parts made of hard materials; some surface damage may result; also used as a grinding and cutting process; expensive tooling and equipment.	V: 50–380; A: 0.1–500; Typically 300 mm^3/min.

Comparison

Wire EDM	Contour cutting of flat or curved surfaces; expensive equipment.	Varies with material and thickness.
Laser-beam machining (LBM)	Cutting and holemaking on thin materials; heat-affected zone; does not require a vacuum; expensive equipment; consumes much energy.	0.50–7.5 m/min.
Electron-beam machining (EBM)	Cutting and holemaking on thin materials; very small holes and slots; heat-affected zone; requires a vacuum; expensive equipment.	1–2 mm^3/min.
Water-jet machining (WJM)	Cutting all types of nonmetallic materials to 25 mm and greater in thickness; suitable for contour cutting of flexible materials; no thermal damage; noisy.	Varies considerably with material.
Abrasive water-jet machining (AWJM)	Single or multilayer cutting of metallic and nonmetallic materials.	Up to 7.5 m/min.
Abrasive-jet machining (AJM)	Cutting, slotting, deburring, deflashing, etching, and cleaning of metallic and nonmetallic materials; manually controlled; tends to round off sharp edges; hazardous.	Varies considerably with material.

Process Selection



Notes: (a) Depends on state of starting surface.
(b) Titanium alloys are generally rougher than nickel alloys.
(c) High-current-density areas.
(d) Low-current-density areas.

Concerns - 4F's

- **Fluids - Dielectric oils, abrasive slurries, etc.**
- **Flushing - Pulse-flushing/ orbiting/ suction flushing/ vibrating electrode. Requires a collection tank**
- **Fumes - Dielectric fumes are not only human health hazards but could be ignited by the EDM spark**
- **Filters - Metal chips, electrode particles and carbon byproducts (sludge) cause dielectric oil breakdown**

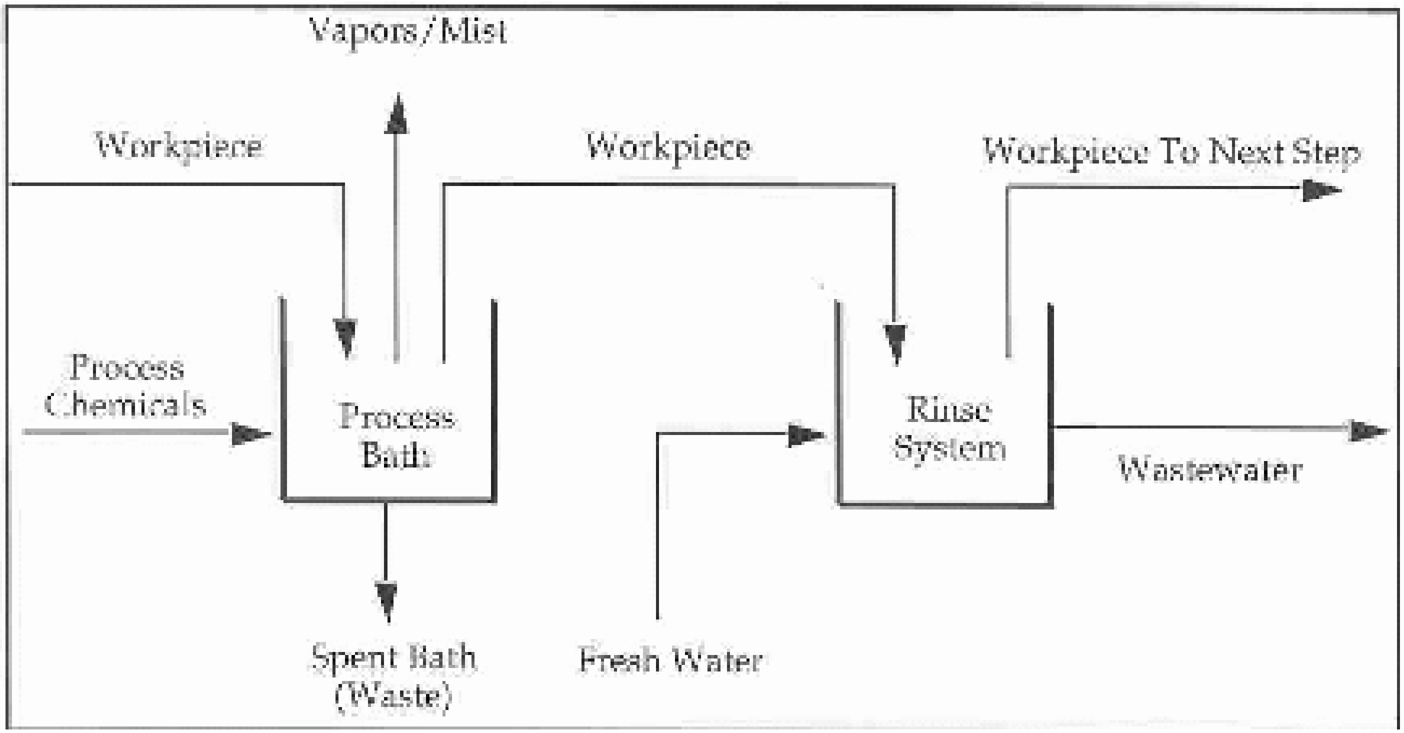
Dielectric Fluids

- **Dielectric fluid is used to provide an insulating barrier when in the "cutting" process**
- **Synthetic, Semi-Synthetic, Petroleum-based**

- **low aromatic content, low sulfur content,**
  high flash point (>180C), low evaporation rate
  low viscosity for good flushing

  All EDM fluids have a high dielectric strength. Too high of a dielectric value will force a smaller gap and may lead to higher electrode wear and lower machining speeds.

Process Wastewater



Process Wastewater

Operations	No. of Sites	Est. Discharge Flow/ Unit (gallon/ year)
Abrasive Jet Machining	1,072	39,977,953
Chemical Milling	726	43,500,663
Electrical Discharge Machining	729	1,714,162
Electrochemical Machining	189	349,183,003
Machining	3156	735,611,690
Painting - Spray/ Brush	1,117	1,349,687,217
Welding	530	1,180,762,371

Other Risk Factors

- Toxic gases and aerosols - Hydrogen
- Electric shock [current density - 10-500 A/cm^2]
- Danger of fire/ damp explosion - short circuit
- Chemical attack by electrolytes
- Effects of the elctromagnetic field
- Proper protection and measures need to be maintained.

Sludge

- **ECM produces large amount of sludge (mix. of oxides and hydroxides of metals). As much as 1.5 times weight of the stock in Fe based alloys. 2-2.5 times wt. in Cr-Ni alloys.**

  Reuse: May be used in pyro- and hydrometallurgy for recovery of valuable elements like Ni, Co, W, Mo, etc., or direct use in manufacture of catalyst and building matls.

  Electrolyte neutralization: Remove hexavalent Cr and nitrates by addition of chemicals.

References

- **Manufacturing Processes for Engineering Materials, Kalpakjian S.**

- **http://www.waterjets.org/about_abrasivejets.html**
- **http://bits.me.berkeley.edu/develop/mattel2/92ANMED.HTM**
- **http://www.cemr.wvu.edu/~imse304/raghav/raghav.htm**
- **http://www.epa.gov/waterscience/guide/mpm/rule.html**
- **http://www.edmoils.com/explain.htm**
- **http://www.unl.edu/nmrc**
- **http://class.et.byu.edu/mfg130/**