Nontraditional Machining Processes

Nontraditional Processes Defined

A group of processes that remove excess material by various techniques involving mechanical, thermal, electrical, or chemical energy (or combinations of these energies) but **do not use a sharp cutting tool** in the conventional sense

NONTRADITIONAL MACHINING AND THERMAL CUTTING PROCESSES

I. Mechanical Energy Processes
II. Electrochemical Machining Processes
III. Thermal Energy Processes
IV. Chemical Machining

Why Nontraditional Processes are Important

- Need to machine newly developed metals and non-metals with special properties that make them difficult or impossible to machine by conventional methods
- Need for unusual and/or complex part geometries that cannot easily be accomplished by conventional machining
- Need to avoid surface damage that often accompanies conventional machining

History of Material Development

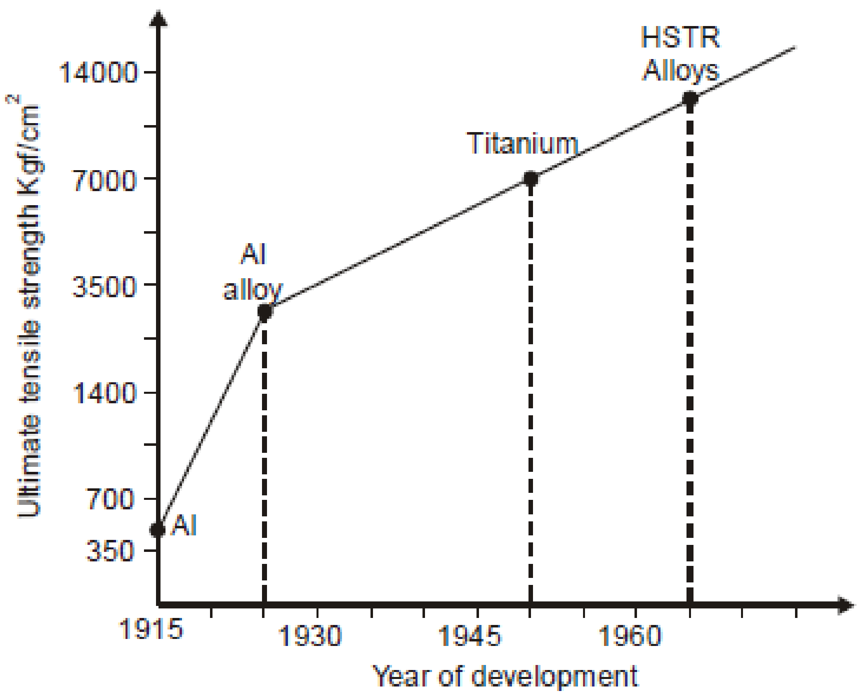


Fig. 1.1. *Trend of increase of material strength*

The requirements that lead to the development of nontraditional machining

- Very high hardness and strength of the material. (above 400 HB.)
- The work piece is too flexible or slender to support the cutting or grinding forces.
- The shape of the part is complex, such as internal and external profiles, or small diameter holes.
- Surface finish or tolerance better than those obtainable conventional process.
- Temperature rise or residual stress in the work piece are undesirable.

Classification of Nontraditional Processes by Type of Energy Used

- *Mechanical* - erosion of work material by a high velocity stream of abrasives or fluid (or both) is the typical form of mechanical action
- *Electrical* - electrochemical energy to remove material (reverse of electroplating)
- *Thermal* – thermal energy usually applied to small portion of work surface, causing that portion to be removed by fusion and/or vaporization
- *Chemical* – chemical etchants selectively remove material from portions of workpart, while other portions are protected by a mask

I. Mechanical Energy Processes

- Ultrasonic machining
- Water jet cutting
- Abrasive water jet cutting
- Abrasive jet machining

Conventional Machining VS NonConventional Machining

- The cutting tool and workpiece are always in physical contact, with a relative motion against each other, which results in friction and a significant *tool wear*.

- In non-traditional processes, there is no physical contact between the tool and workpiece. Although in some non-traditional processes tool wear exists, it rarely is a significant problem.

- Material removal rate of the traditional processes is limited by the mechanical properties of the work material. Non-traditional processes easily deal with such difficult-to-cut materials like ceramics and ceramic based tool materials, fiber reinforced materials, carbides, titanium-based alloys.

Continue…

- In traditional processes, the relative motion between the tool and work piece is typically rotary or reciprocating. Thus, the shape of the work surfaces is limited to circular or flat shapes. In spite of widely used CNC systems, machining of three-dimensional surfaces is still a difficult task. Most non-traditional processes were develop just to solve this problem.

- Machining of small cavities, slits, blind or through holes is difficult with traditional processes, whereas it is a simple work for some non-traditional processes.

- Traditional processes are well established, use relatively simple and inexpensive machinery and readily available cutting tools. Non-traditional processes require expensive equipment and tooling as well as skilled labor, which increases significantly the production cost.

Classification OF Processes

- Mechanical Metal removal Processes
- It is characterized by the fact that the material removal is due to the application of mechanical energy in the form of high frequency vibrations or kinetic energy of an abrasive jet.

- 1. Ultra sonic Machining (USM).
  2. Abrasive Jet Machining (AJM).
  3. Water Jet Machining (WJM).

Continue…

- Electro-Chemical
- It is based on electro-chemical dissolution of materials by an electrolyte under the influence of an externally applied electrical potential.

  1. Electro-Chemical Machining (ECM).
  2. ECG
  3 ECD

Continue…

- Thermal Method

The material is removed due to controlled, localized heating of the work piece. It result into material removal by melting and evaporation.

The source of heat generation in such cases can be widely different.

1.Electric Discharge Machining (EDM).

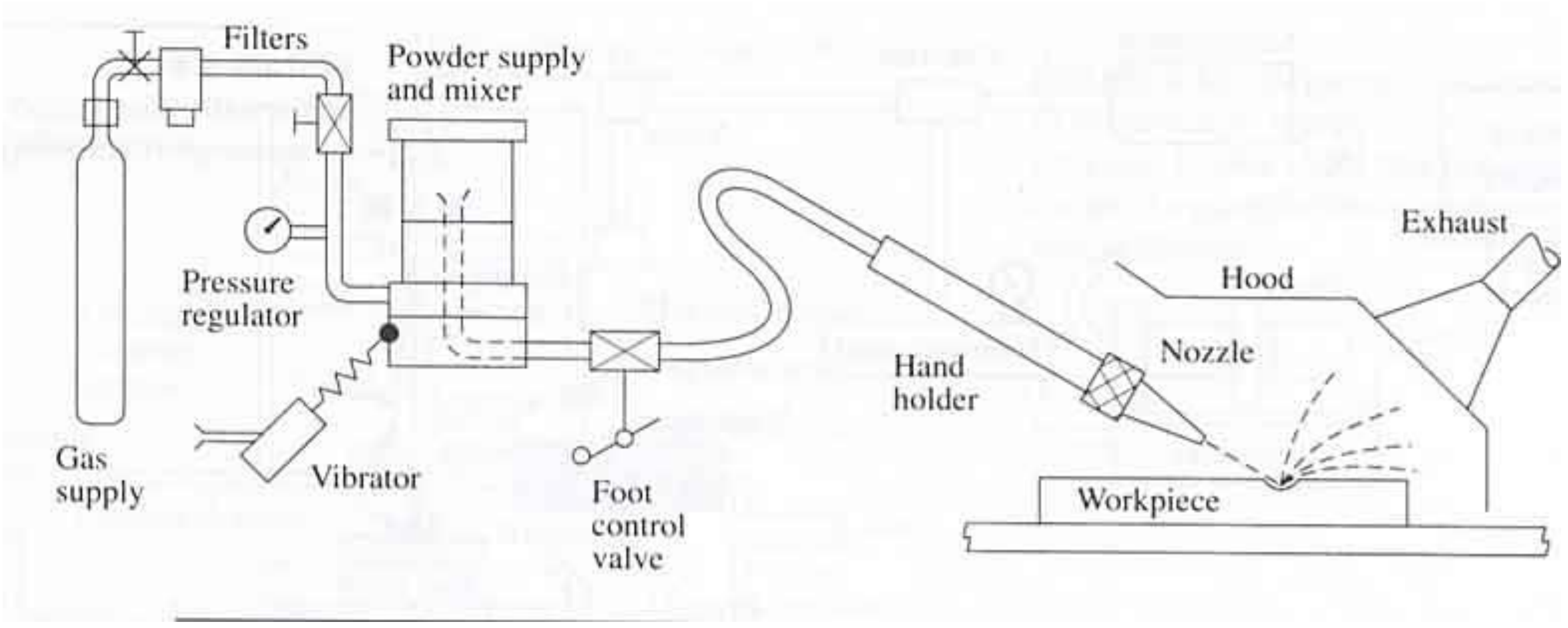
2. Plasma Arc Machining (PAM).

3. EBM   4. LBM

Abrasive Jet Cutting

- A stream of fine grain abrasives mixed with air or suitable carrier gas, at high pressure, is directed by means of a nozzle on the work surface to be machined.
- The material removal is due to erosive action of a high pressure jet.
- AJM differs from the conventional sandblasting process in the way that the abrasive is much finer and has effective control over the process parameters and cutting. Used mainly to cut hard and brittle materials, which are thin and sensitive to heat.

Abrasive Jet Machining Setup



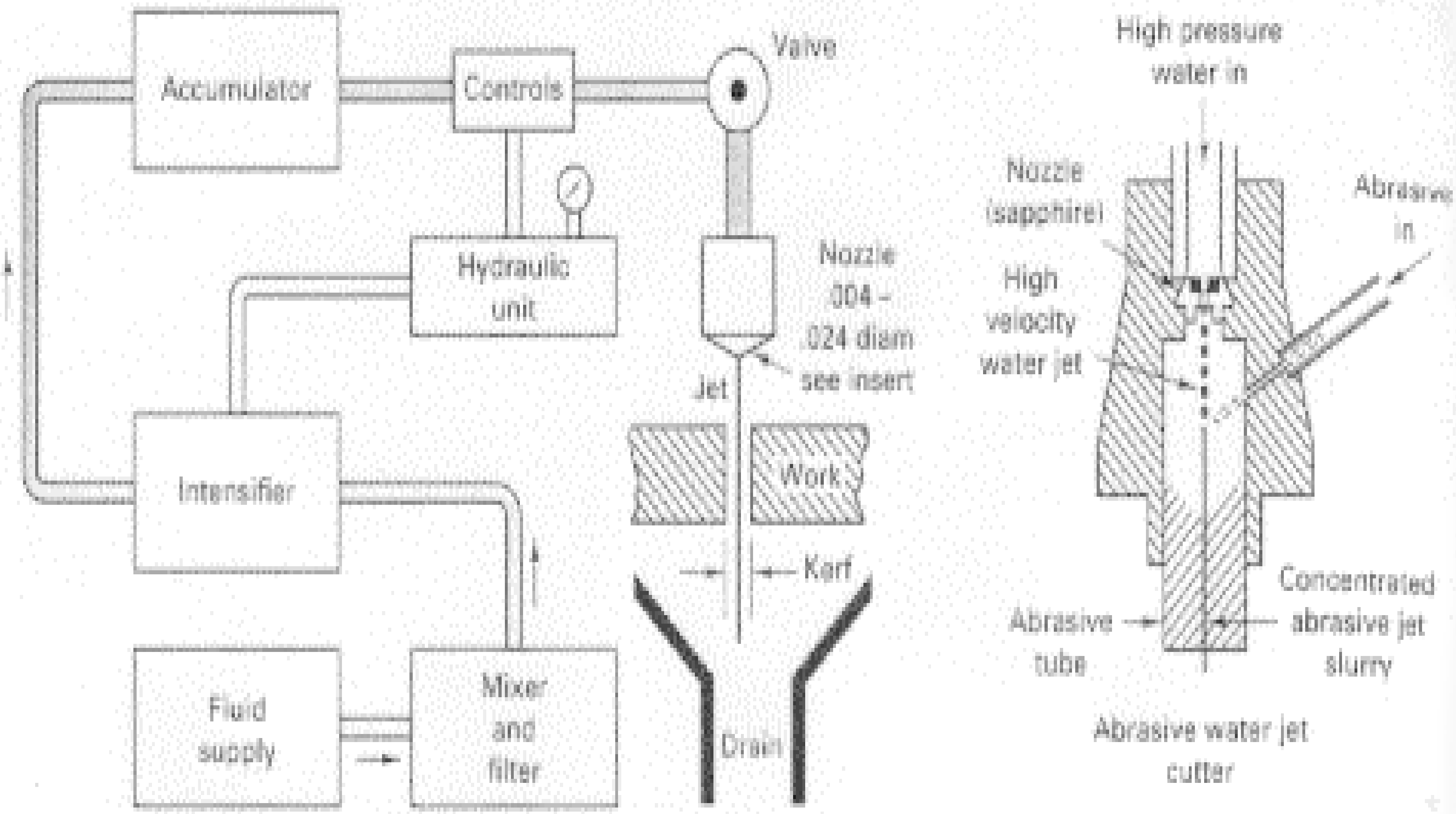


FIGURE 32-15 Schematic of hydrodynamic jet machining. The intensifier elevates the fluid to the desired nozzle pressure while the accumulator smooths out the pulses in the fluid jet. Schematic of an abrasive waterjet machining nozzle is shown on the right.

Typical AJM Parameters

- Abrasive
  - Aluminum oxide for Al and Brass.
  - SiC for Stainless steel and Ceramic\
  - Bicarbonate of soda for Teflon
  - Glass bed for polishing.
- Size
  - 10-15 Micron
- Quantity
  - 5-15 liter/min for fine work
  - 10-30 liter/min for usual cuts.
  - 50-100 liter/min for rough cuts.

Typical AJM Parameters

- Medium
  - Dry air, $CO_{2,}$ N_2
  - Quantity: 30 liter/min
  - Velocity: 150-300 m/min
  - Pressure: 200-1300 KPa
- Nozzle
  - Material: Tungsten carbide or saffire
  - Stand of distance: 2.54-75 mm
  - Diameter: 0.13-1.2 mm
  - Operating Angle: 60° to vertical

Typical AJM Parameters

- Factors affecting MRR:
  - Types of abrasive and abrasive grain size
  - Flow rate
  - Stand off distance
  - Nozzle Pressure

- **Advantages of AJM**
- Low capital cost.
- Less vibration.
- Good for difficult to reach area.
- No heat is generated in work piece.
- Ability to cut intricate holes of any hardness and brittleness in the material.
- Ability to cut fragile, brittle hard and heat sensitive material without damage

- **Disadvantages of AJM:**
- Low metal removal rate.
- Due to stay cutting accuracy is affected.
- Particles are embedding in the workpiece.
- Abrasive powder cannot be reused.

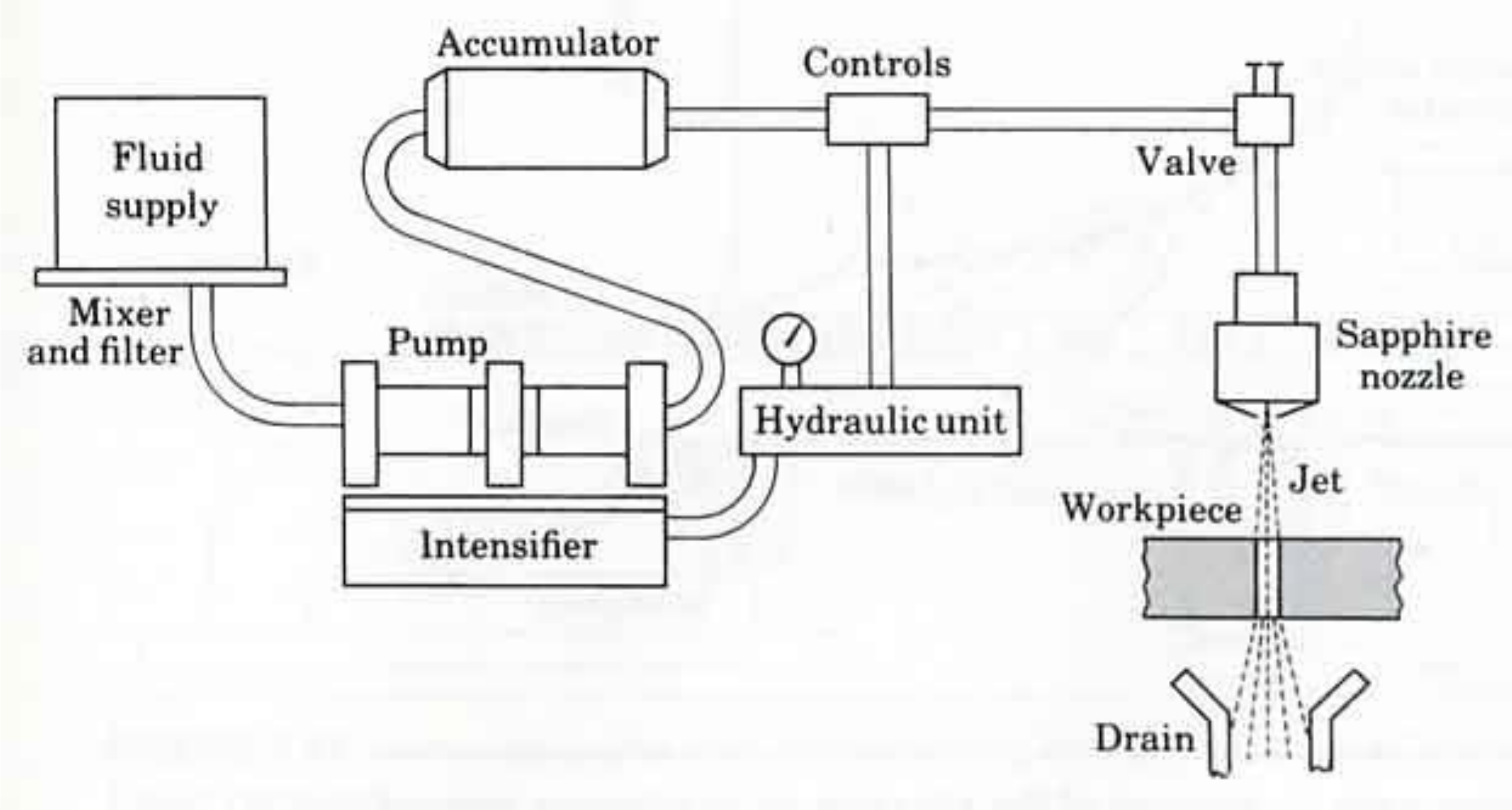
- **<u>Applications of AJM:</u>**

- For abrading and frosting glass, it is more economical than acid etching and grinding.
- For doing hard surface safe removal of smears and ceramics oxides on metals.
- Resistive coating from ports to delicate to withstand normal scrapping.
- Delicate cleaning such as removal of smudges from antique documents.
- Machining semiconductors such as germanium etc.

Water Jet Machining

- The water jet machining involves directing a high pressure (150-1000 MPa) high velocity (540-1400 m/s) water jet(faster than the speed of sound) to the surface to be machined. The fluid flow rate is typically from 0.5 to 2.5 l/min
- The kinetic energy of water jet after striking the work surface is reduced to zero.
- The bulk of kinetic energy of jet is converted into pressure energy.
- If the local pressure caused by the water jet exceeds the strength of the surface being machined, the material from the surface gets eroded and a cavity is thus formed.
- The water jet energy in this process is concentrated over a very small area, giving rise to high energy density(10^{10} w/mm^2) High

Water Jet Machining Setup



Continue…

- Water is the most common fluid used, but additives such as alcohols, oil products and glycerol are added when they can be dissolved in water to improve the fluid characteristics.
- Typical work materials involve soft metals, paper, cloth, wood, leather, rubber, plastics, and frozen food.
- If the work material is brittle it will fracture, if it is ductile, it will cut well:
- The orifice is often made of sapphire and its diameter rangesfrom 1.2 mm to 0.5 mm:

Water Jet Equipments

- It is consists of three main units

  (i) A pump along with intensifier.

  (ii)Cutting head comprising of nozzle and work table movement.

  (iii) filter unit for debries,pout impurities.

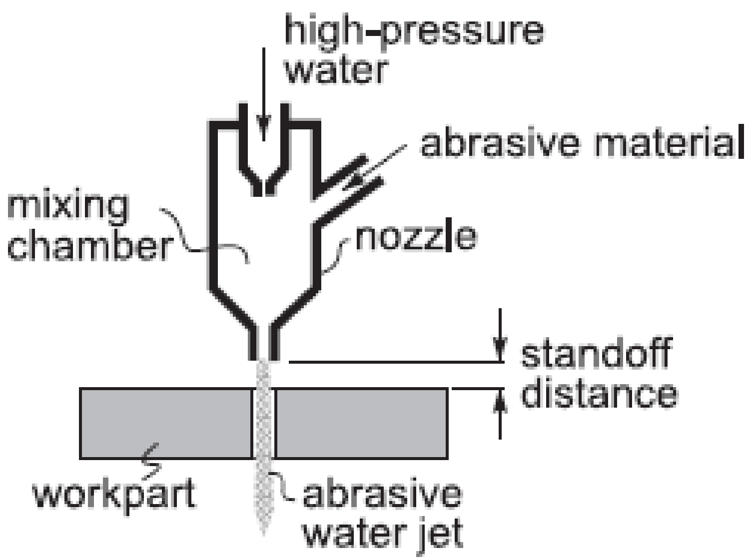
- Advantages

  - no heat produced
  - cut can be started anywhere without the need for predrilled holes
  - burr produced is minimum
  - environmentally safe and friendly manufacturing.

Application – used for cutting composites, plastics, fabrics, rubber, wood products etc. Also used in food processing industry.

Abrasive Water jet machining

- The rate of cutting in water jet machining, particularly while cutting ductile material, is quite low. Cutting rate can be achieved by mixing abrasive powder in the water to be used for machining.
- In *Abrasive Water Jet Cutting*, a narrow, focused, water jet is mixed with abrasive particles.
- This jet is sprayed with very high pressures resulting in high velocities that cut through all materials.
- The presence of abrasive particles in the water jet reduces cutting forces and enables cutting of thick and hard materials (steel plates over 80-mm thick can be cut).
- The velocity of the stream is up to 90 m/s, about 2.5 times the speed of sound.



Abrasive Water Jet Cutting.

Abrasive Jet Cutter.

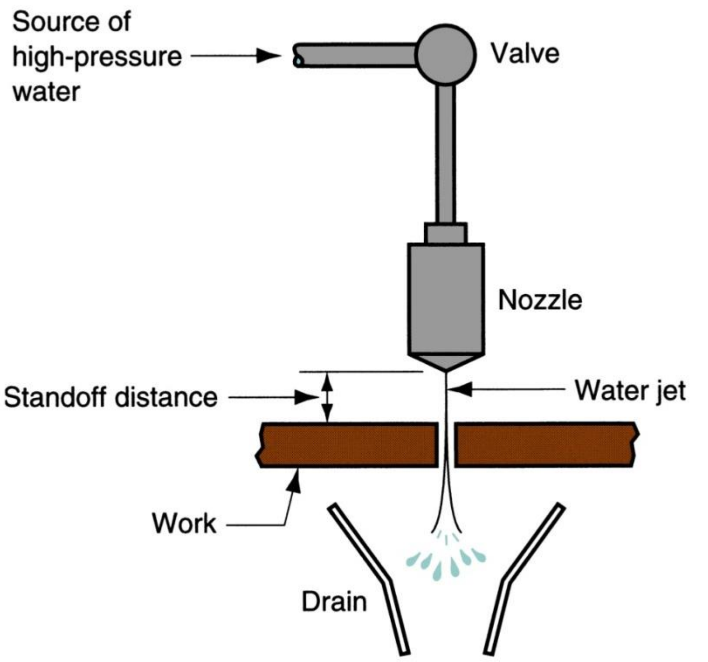
Continue..

- Abrasive Water Jet Cutting process was developed in 1960s to cut materials that cannot stand high temperatures for stress distortion or metallurgical reasons such as wood and composites, and traditionally difficult-to-cut materials, e.g. ceramics, glass, stones, titanium alloys



Water Jet Cutting (WJC)

Uses a fine, high pressure, high velocity stream of water directed at work surface for cutting



WJC Applications

- Usually automated by CNC or industrial robots to manipulate nozzle along desired trajectory
- Used to cut narrow slits in flat stock such as plastic, textiles, composites, floor tile, carpet, leather, and cardboard
- Not suitable for brittle materials (e.g., glass)
- WJC advantages: no crushing or burning of work surface, minimum material loss, no environmental pollution, and ease of automation

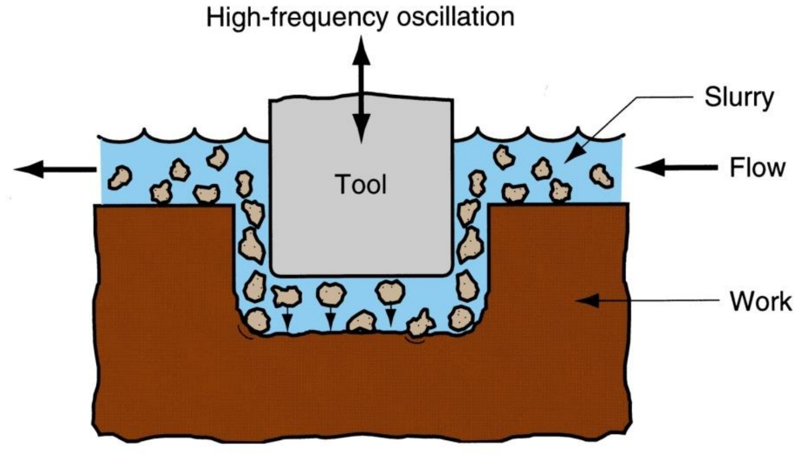
Abrasive Water Jet Cutting (AWJC)

- When WJC is used on metals, abrasive particles must be added to jet stream usually

Ultrasonic Machining (USM)

Abrasives contained in a slurry are driven at high velocity against work by a tool vibrating at low amplitude and high frequency

- Tool oscillation is perpendicular to work surface
- Tool is fed slowly into work
- Shape of tool is formed in pa



USM Applications

- Hard, brittle work materials such as ceramics, glass, and carbides
- Also successful on certain metals, such as stainless steel and titanium
- Shapes include non-round holes, holes along a curved axis
- “Coining operations” - pattern on tool is imparted to a flat work surface

Ultrasonic Waves

- The Ultrasonic waves are sound waves of frequency higher than 20,000 Hz.
- Ultrasonic waves can be generated using mechanical, electromagnetic and thermal energy sources.
- They can be produced in gasses (including air), liquids and solids.
- Magnetostrictive transducers use the inverse magnetostrictive effect to convert magnetic energy into ultrasonic energy
- This is accomplished by applying a strong alternating magnetic field to certain metals, alloys and ferrites

Continue..

- Piezoelectric transducers employ the inverse piezoelectric effect using natural or synthetic single crystals (such as quartz) or ceramics (such as barium titanate) which have strong piezoelectric behavior.
- Ceramics have the advantage over crystals in that they are easier to shape by casting, pressing and extruding.

Principle of machining

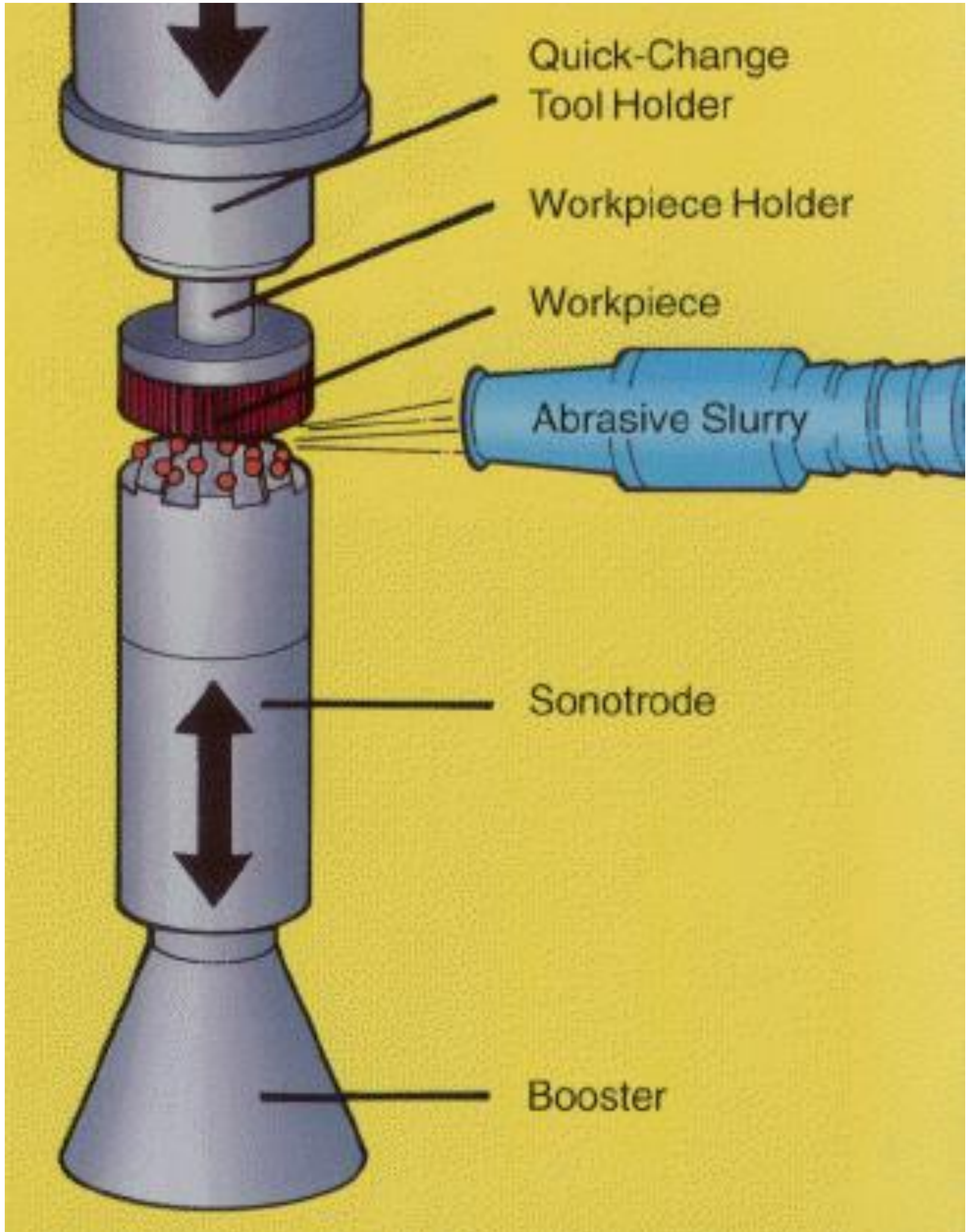
- In the process of Ultrasonic Machining, material is removed by micro-chipping or erosion with abrasive particles.
- In USM process, the tool, made of softer material than that of the workpiece, is oscillated by the Booster and Sonotrode at a frequency of about 20 kHz with an amplitude of about 25.4 um (0.001 in).
- The tool forces the abrasive grits, in the gap between the tool and the workpiece, to impact normally and successively on the work surface, thereby machining the work surface.
- During one strike, the tool moves down from its most upper remote position with a starting speed at zero, then it speeds up to finally reach the maximum speed at the mean position.

Continue..

- Then the tool slows down its speed and eventually reaches zero again at the lowest position.
- When the grit size is close to the mean position, the tool hits the grit with its full speed
- The smaller the grit size, the lesser the momentum it receives from the tool.
- Therefore, there is an effective speed zone for the tool and, correspondingly there is an effective size range for the grits.
- In the machining process, the tool, at some point, impacts on the largest grits, which are forced into the tool and work piece.

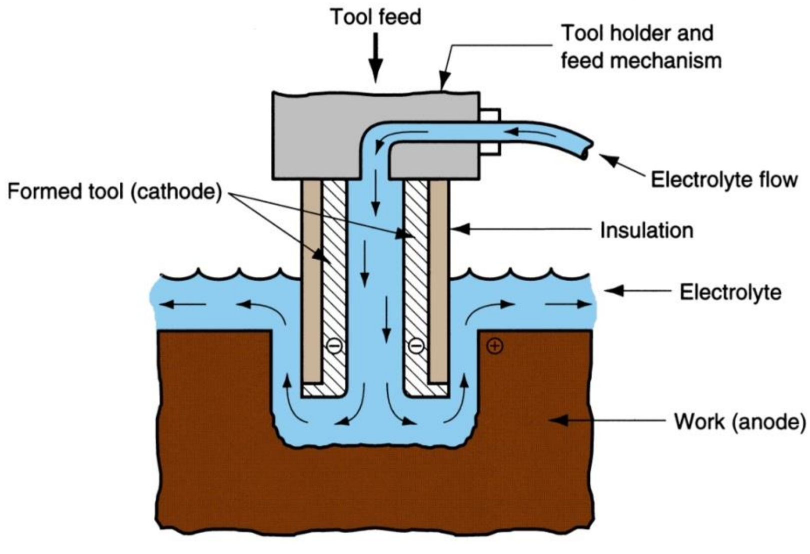
Continue..

- As the tool continues to move downwards, the force acting on these grits increases rapidly, therefore some of the grits may be fractured.
- As the tool moves further down, more grits with smaller sizes come in contact with the tool, the force acting on each grit becomes less.
- Eventually, the tool comes to the end of its strike, the number of grits under impact force from both the tool and the workpiece becomes maximum.
- Grits with size larger than the minimum gap will penetrate into the tool and work surface to different extents according to their diameters and the hardness of both surfaces


Quick-Change
Tool Holder
Workpiece Holder
Workpiece
Abrasive Slurry
Sonotrode
Booster

Electrochemical Machining (ECM)

Material removal by anodic dissolution, using electrode (tool) in close proximity to the work but separated by a rapidly flowing electrolyte



Electrochemical Machining

- A popular application of electrolysis is the *electroplating* process in which metal coatings are deposited upon the surface of a catholically polarized metal.

- ECM is similar to electro polishing in that it also is an anodic dissolution process. But the rates of metal removal offered by the polishing process are considerably less than those needed in metal machining practice .

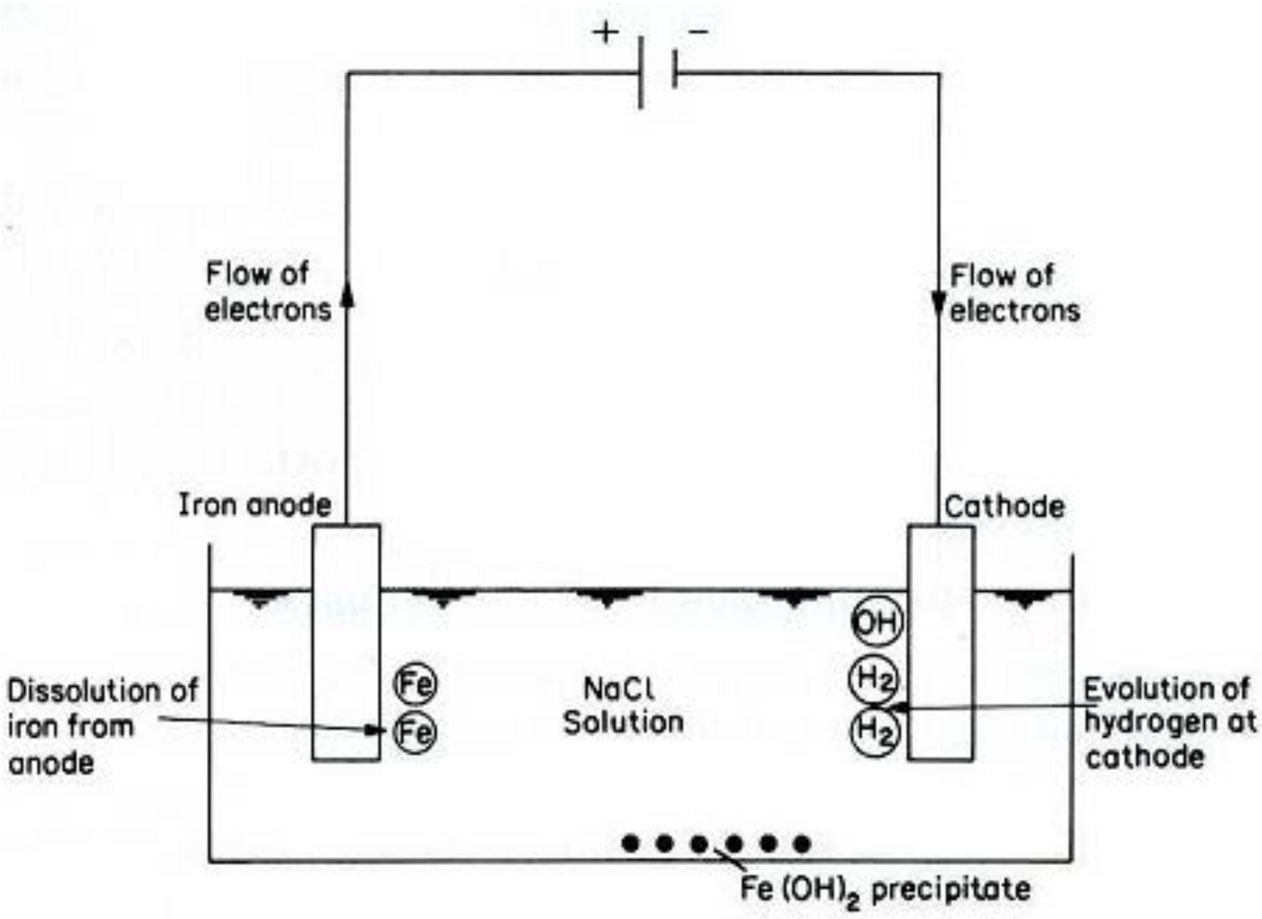
Concept

- Metal removal is achieved by electrochemical dissolution of an anodically polarized workpiece which is one part of an electrolytic cell in ECM.

- when an electric current is passed between two conductors dipped into a liquid solution named as Electrolysis .

- Electrolytes are different from metallic conductors of electricity in that the current is carried not by electrons but by atoms, or group of atoms, which have either lost or gained electrons, thus acquiring either positive or negative charges. Such atoms are called ions.

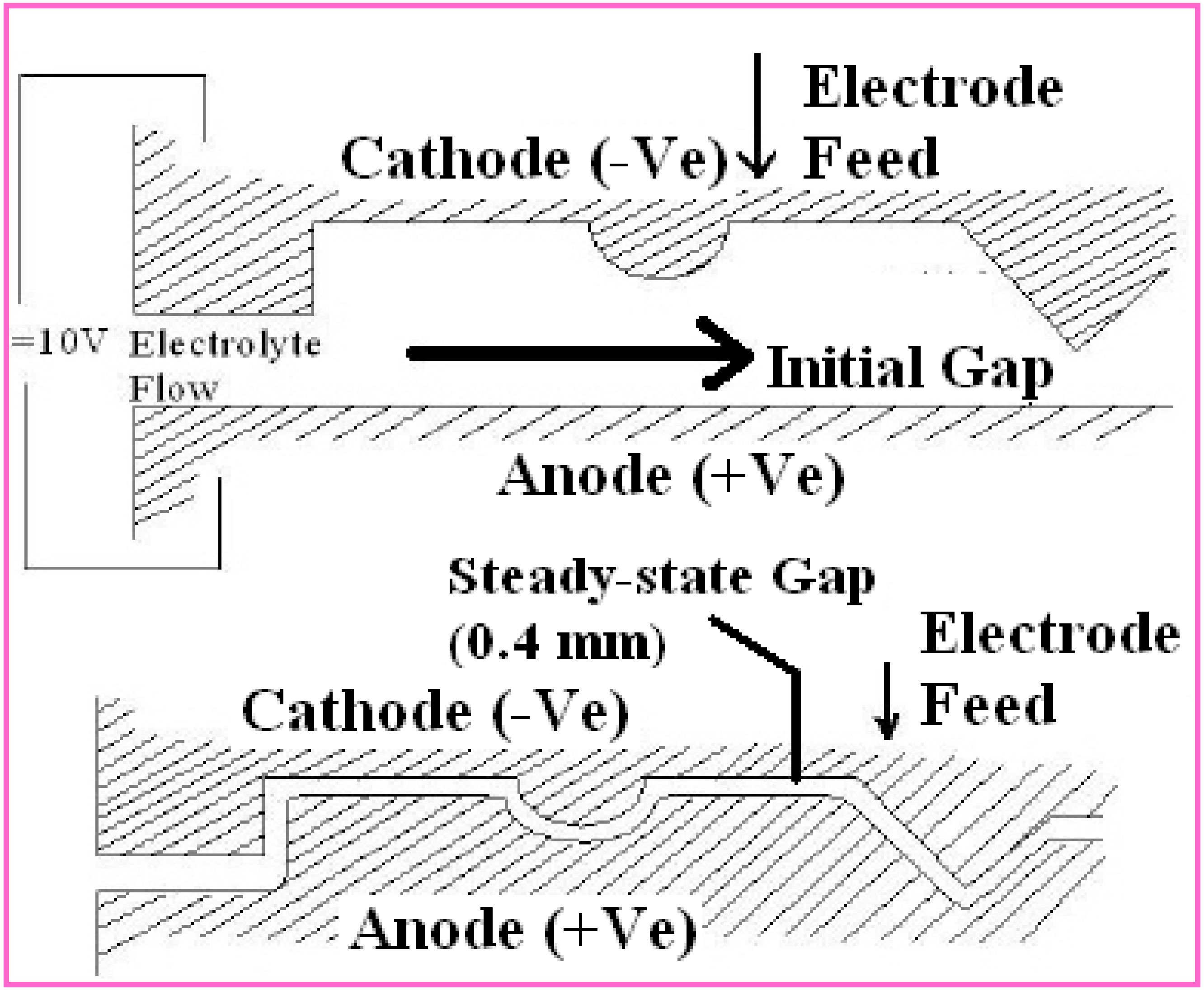
Electrolytic dissolution of iron.



Continue..

- Ions which carry positive charges move through the electrolyte in the direction of the positive current, that is, toward the cathode, and are called cat anions.
- The negatively charged ions travel toward the anode and are called anions.
- The movement of the ions is accompanied by the flow of electrons, in the opposite sense to the positive current in the electrolyte.
- Both reactions are a consequence of the applied potential difference, that is, voltage, from the electric source.

Working Principle



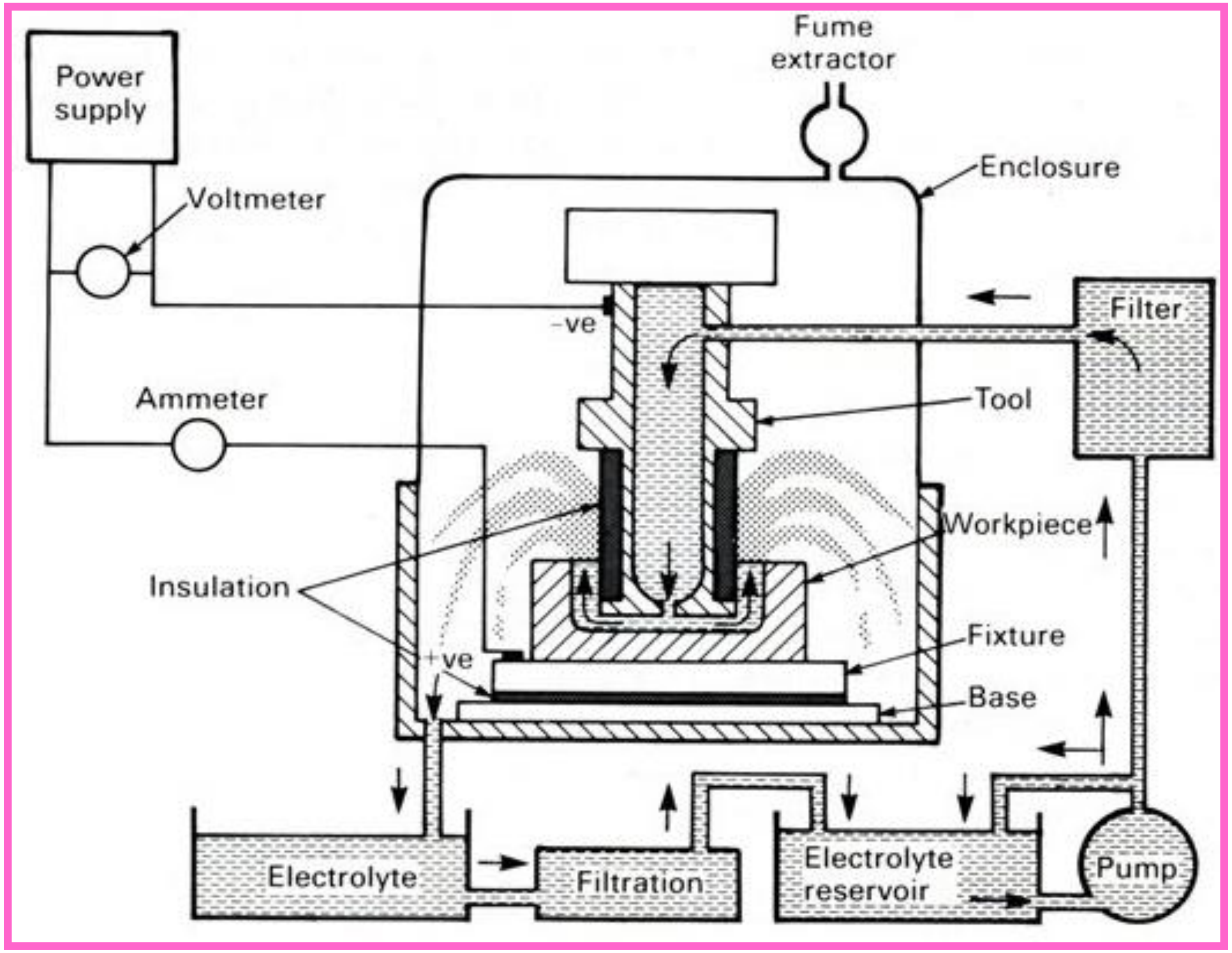
Continue..

- the workpiece and tool are the anode and cathode, respectively, of an electrolytic cell, and a constant potential difference, usually at about 10 V, is applied across them.
- A suitable electrolyte, for example, aqueous sodium chloride (table salt) solution, is chosen so that the cathode shape remains unchanged during electrolysis.
- The electrolyte is also pumped at a rate 3 to 30 meter/second, through the gap between the electrodes to remove the products of machining and to diminish unwanted effects, such as those that arise with cathodic gas generation and electrical heating.
- The rate at which metal is then removed from the anode is approximately in inverse proportion to the distance between the electrodes

Continue..

- As machining proceeds, and with the simultaneous movement of the cathode at a typical rate, for example, 0.02 millimeter/second toward the anode.
- the gap width along the electrode length will gradually tend to a steady-state value. Under these conditions, a shape, roughly complementary to that of the cathode, will be reproduced on the anode.

Schematic diagram



ECM Components (Power)

- The power needed to operate the ECM is obviously electrical. There are many specifications to this power.
- The current density must be high.
- The gap between the tool and the work piece must be low for higher accuracy, thus the voltage must be low to avoid a short circuit.
- The control system uses some of this electrical power.

ECM Components (electrolyte circulation system)

- The electrolyte must be injected in the gap at high speed (between 1500 to 3000 m/min).
- The inlet pressure must be between 0.15-3 MPa.
- The electrolyte system must include a fairly strong pump.
- System also includes a filter, sludge removal system, and treatment units.
- The electrolyte is stored in a tank.

ECM Components (control system)

- Control parameters include:
  - Voltage
  - Inlet and outlet pressure of electrolyte
  - Temperature of electrolyte.
- The current is dependant on the above parameters and the feed rate.

Advantages

- There is no cutting forces therefore clamping is not required except for controlled motion of the work piece.
- There is no heat affected zone.
- Very accurate.
- Relatively fast
- Can machine harder metals than the tool
- Faster than EDM
- No tool wear at all.
- No heat affected zone.
- Better finish and accuracy.

Disadvantages

- 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.
- Material has to be electrically conductive.

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.

- Sinking operations (RAM ECM) are also used as an alternative to RAM EDM.

- 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 that would be really difficult to perform on conventional machines.

- 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.

Economics

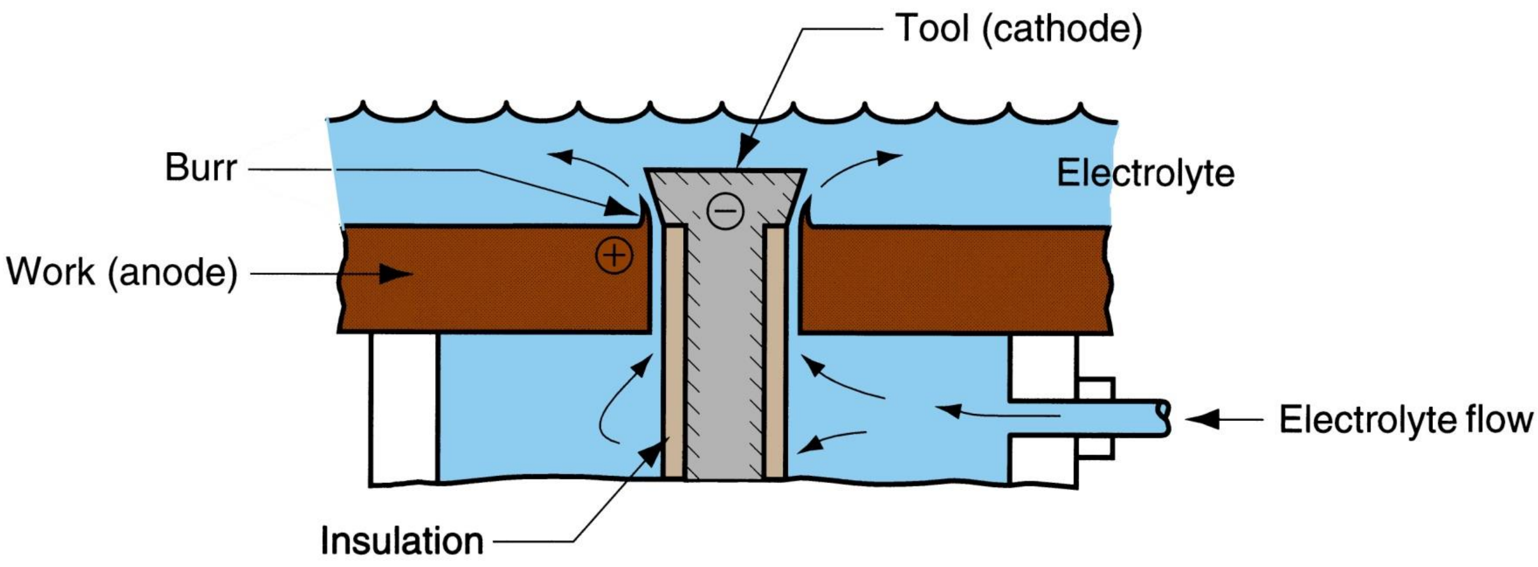
- The process is economical when a large number of complex identical products need to be made (at least 50 units).

- Several tools could be connected to a cassette to make many cavities simultaneously. (i.e. cylinder cavities in engines).

- Large cavities are more economical on ECM and can be processed in 1/10 the time of EDM.

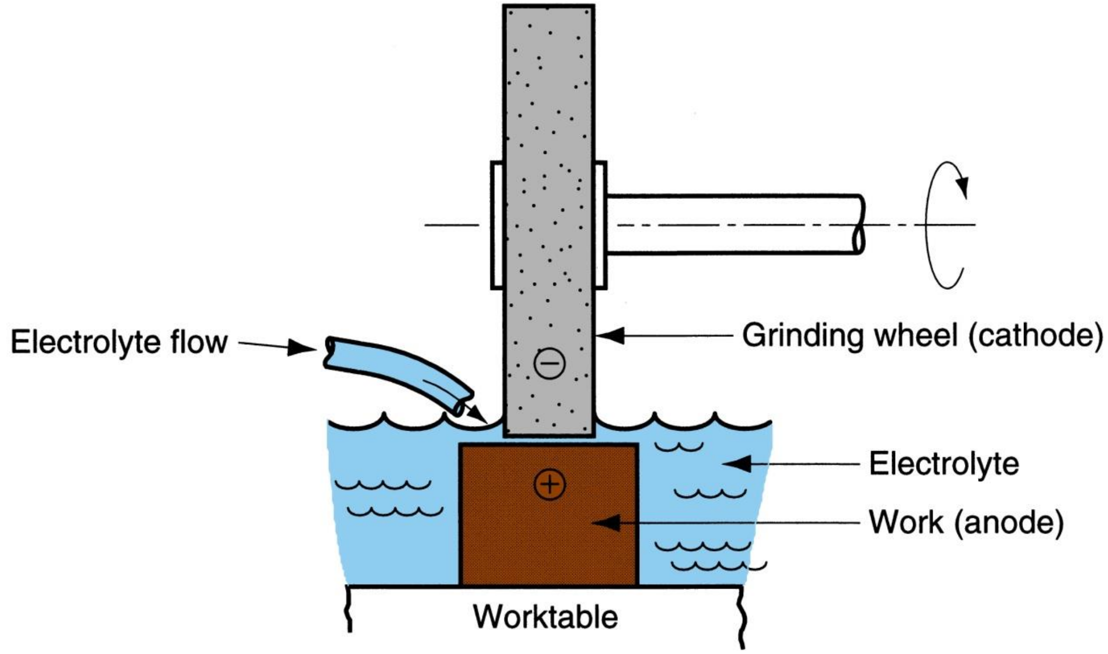
Electrochemical Deburring (ECD)

Adaptation of ECM to remove burrs or round sharp corners on holes in metal parts produced by conventional through-hole drilling

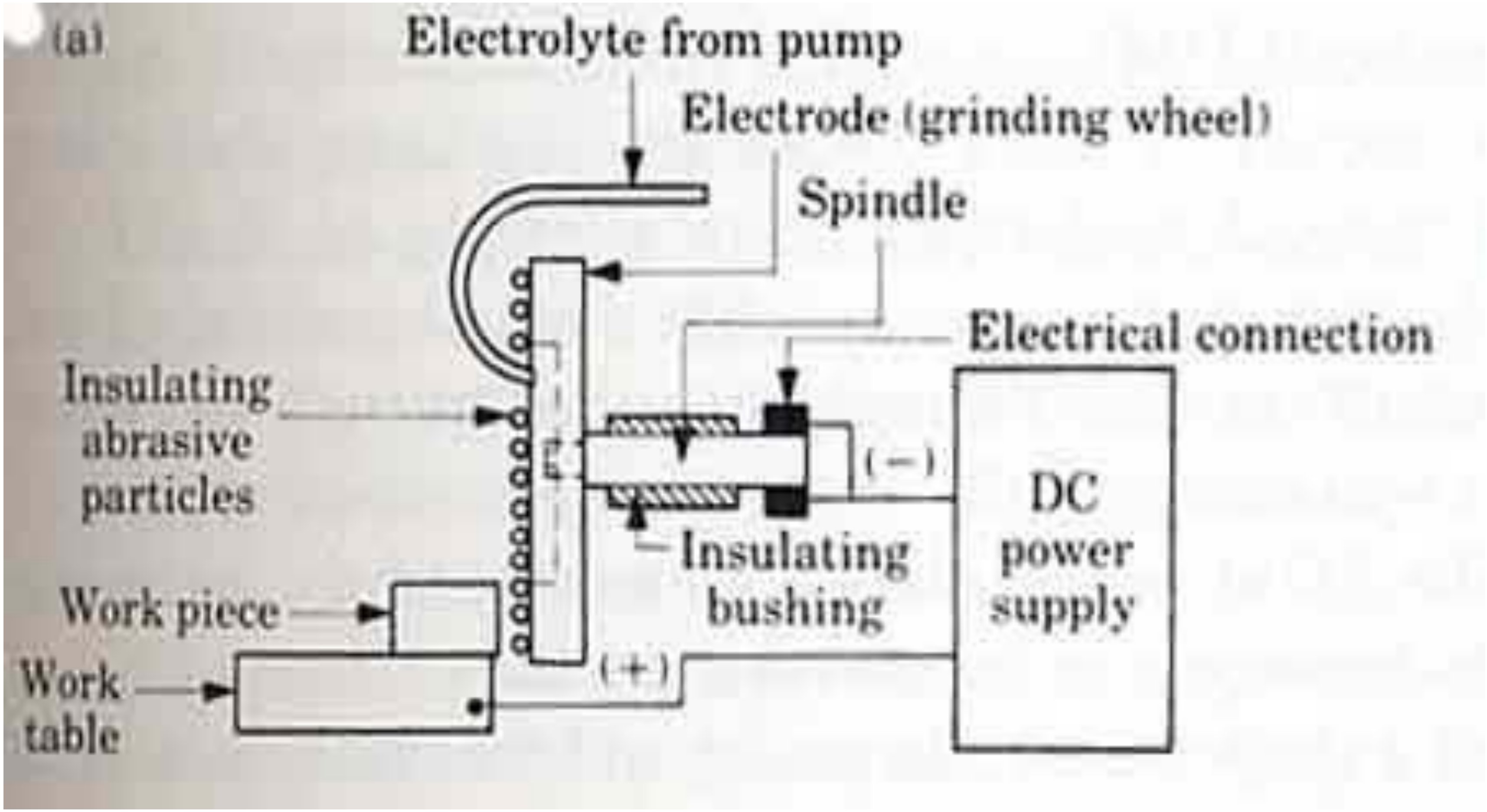


Electrochemical Grinding (ECG)

Special form of ECM in which a grinding wheel with conductive bond material is used to augment anodic dissolution of metal part surface



ELECTROCHEMICAL GRINDING



Concept

- The main feature of electrochemical grinding (ECG) is the use of a grinding wheel in which an insulating abrasive, such as diamond particles, is set in a conducting material. This wheel becomes the cathode tool .
- The non conducting particles act as a spacer between the wheel and workpiece, providing a constant inter electrode gap, through which electrolyte is flushed.
- Accuracies achieved by ECG are usually about 0.125 millimeter. A drawback of ECG is the loss of accuracy when inside corners are ground. Because of the electric field effects, radii better than 0.25 � 0.375 millimeter can seldom be achieved
- A wide application of electrochemical grinding is the production of tungsten carbide cutting tools. ECG is also useful in the grinding of fragile parts such as hypodermic needles

Concept

- Combines electrochemical machining with conventional grinding.

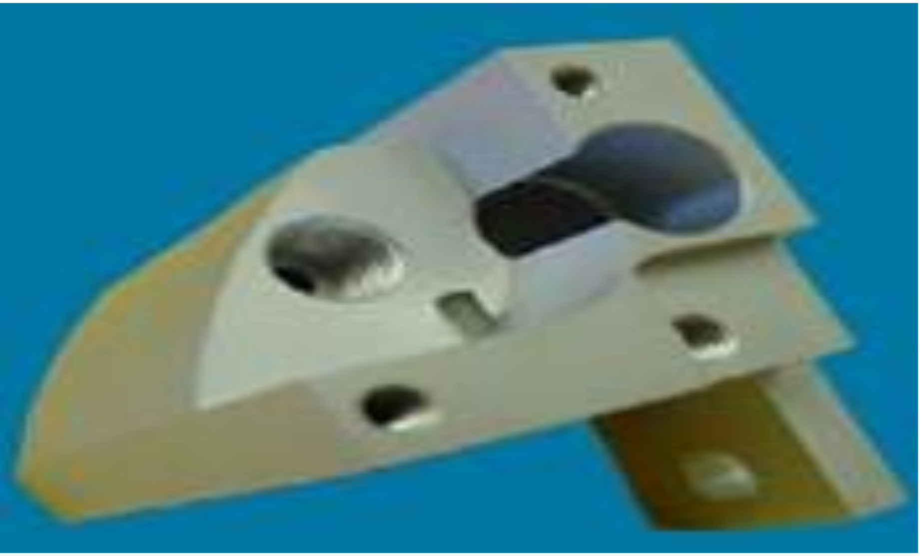
- The equipment used is similar to conventional grinder except that the wheel is a rotating cathode with abrasive particles.

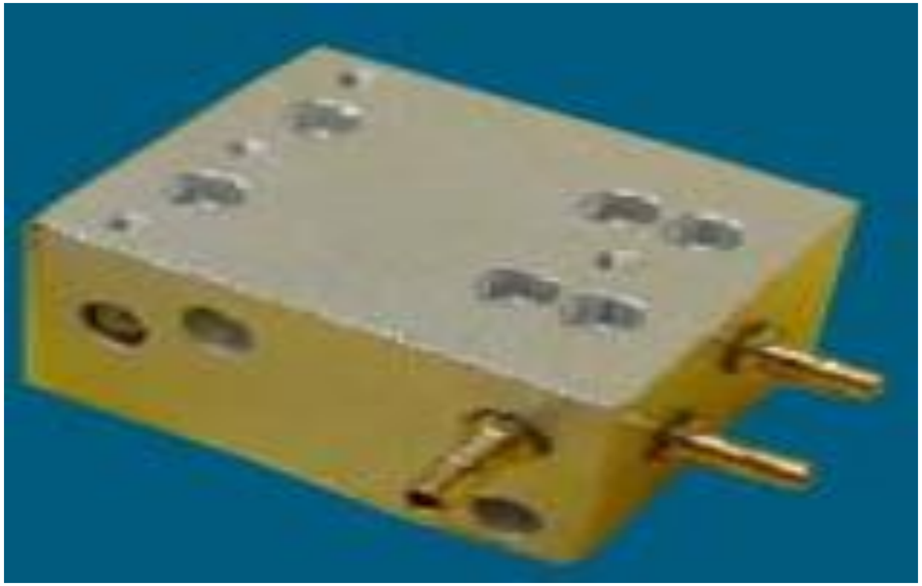
- The wheel is metal bonded with diamond or Al oxide abrasives.

- Abrasives serve as insulator between wheel and work piece. A flow of electrolyte (sodium nitrate) is provided for electrochemical machining.

- Suitable in grinding very hard materials where wheel wear can be very high in traditional grinding

Sample ECMed parts





III. Thermal Energy Processes

- Very high local temperatures
  - Material is removed by fusion or vaporization
- Physical and metallurgical damage to the new work surface
- In some cases, resulting finish is so poor that subsequent processing is required

Thermal Energy Processes

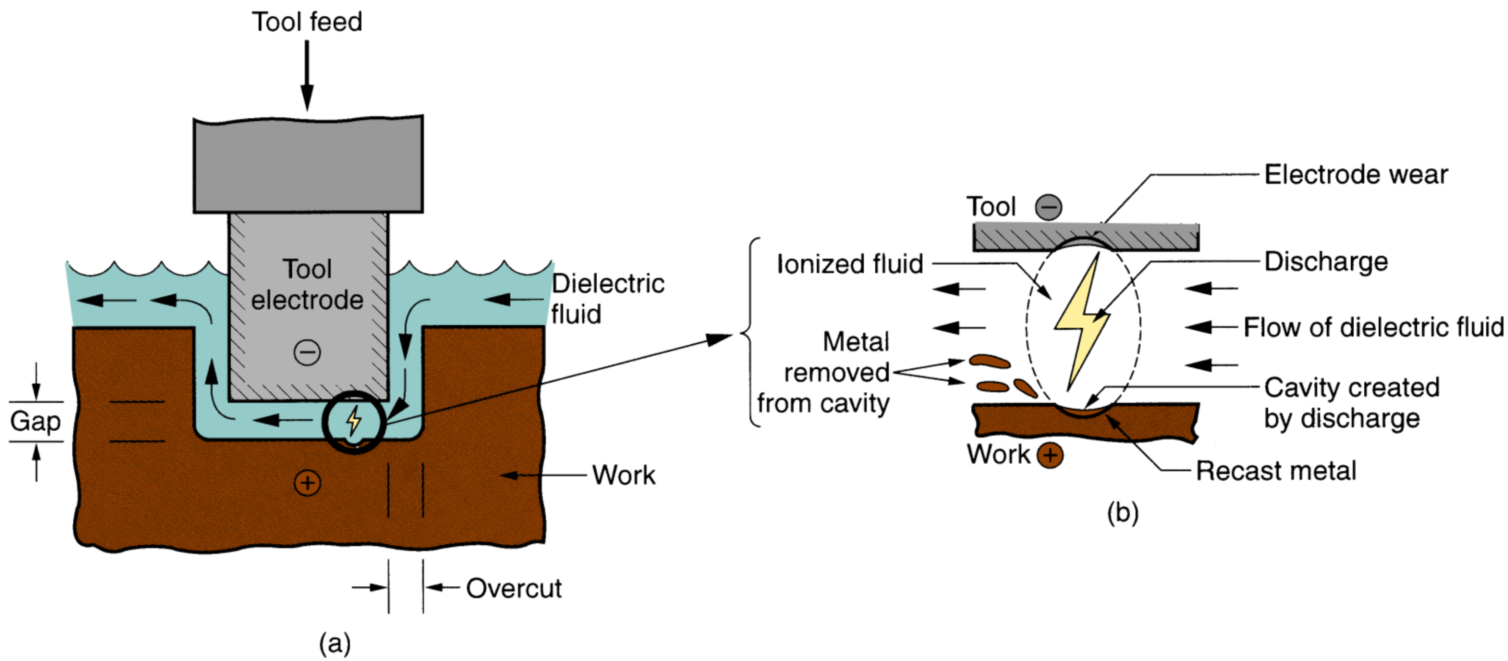
- Electric discharge machining
- Electric discharge wire cutting
- Electron beam machining
- Laser beam machining
- Plasma arc machining

Electric Discharge Processes

Metal removal by a series of discrete electrical discharges (sparks) causing localized temperatures high enough to melt or vaporize the metal

- Can be used only on electrically conducting work materials
- Two main processes:
  1. Electric discharge machining
  2. Wire electric discharge machining

Electric Discharge Machining (EDM)



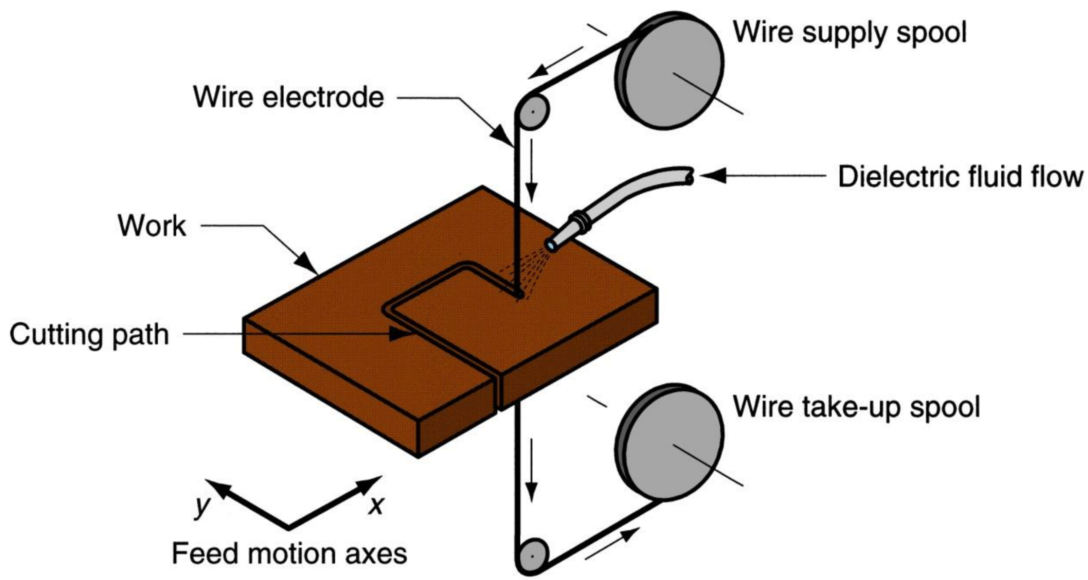
Electric discharge machining (EDM): (a) overall setup, and (b) close-up view of gap, showing discharge and metal removal

EDM Applications

- Tooling for many mechanical processes: molds for plastic injection molding, extrusion dies, wire drawing dies, forging and heading dies, and sheetmetal stamping dies
- Production parts: delicate parts not rigid enough to withstand conventional cutting forces, hole drilling where hole axis is at an acute angle to surface, and machining of hard and exotic metals

Wire EDM

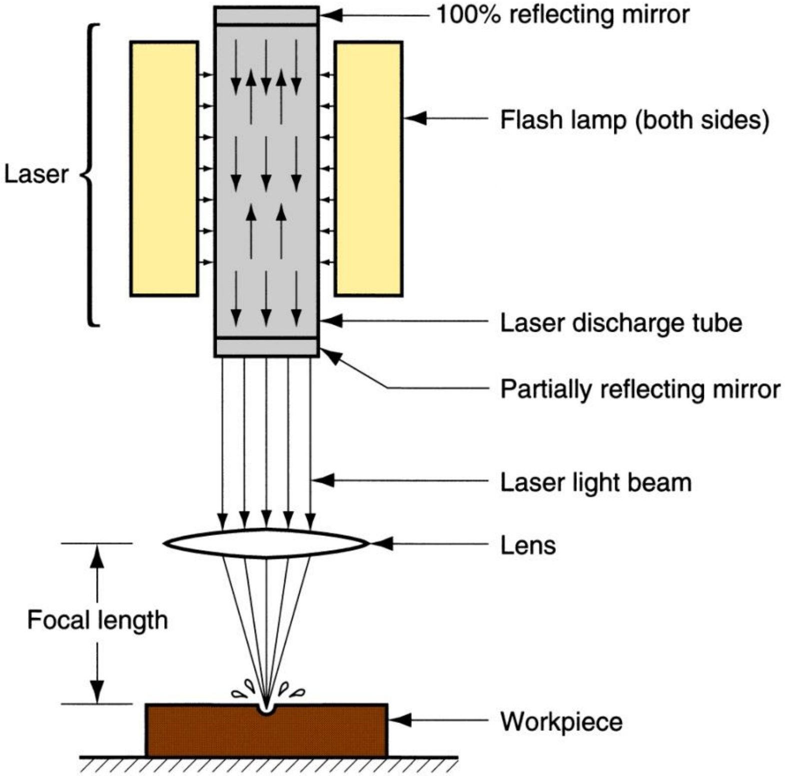
Special form of EDM that uses small diameter wire as electrode to cut a narrow kerf in work



Electric discharge wire cutting (EDWC), also called wire EDM

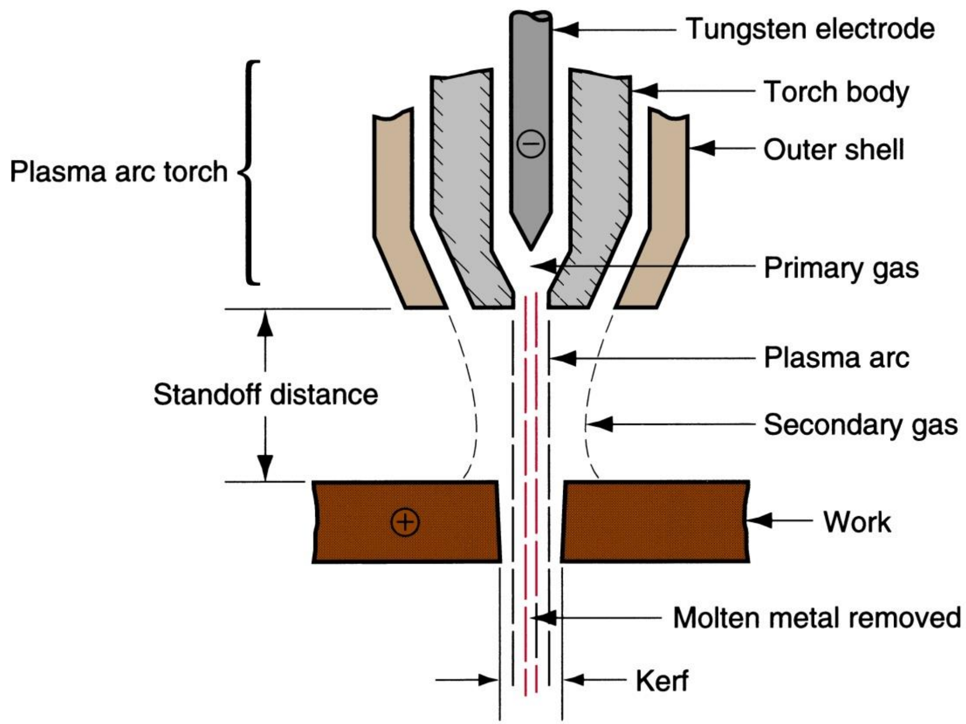
Laser Beam Machining (LBM)

Uses the light energy from a laser to remove material by vaporization and ablation



Plasma Arc Cutting (PAC)

Uses a plasma stream operating at very high temperatures to cut metal by melting



Electrical Discharge Machining (EDM)

- Also known as spark erosion machining.
- Based on the erosion of metals by spark discharges.
- When an arc is produced between two metals, part of the metal is eroded.
- This erosion process, when controlled, can create a desired shape.
- Only works with materials that are electrical conductors.

Basic EDM Operation

- Tool and the workpiece are connected to a DC power supply.
- An electrode with the desired shape is cut and secured to the machine ram.
- Work is secured to a table an immersed in a tank containing a dielectric fluid typically mineral oils or deionized water).
- If potential between tool (electrode) and work is high enough, a spark is discharged across the fluid.

Basic EDM Operation

- Spark removes a small amount of metal from workpiece.
- Discharges are repeated many times.
- Gap: space between tool and workpiece - very critical.
- Downfeed (Z motion) is NC controlled to maintain constant gap.
- No mechanical energy required: hardness, strength, toughness don’t affect material removal rate (MRR).

EDM Parameters

- Current
  - Surface Finish is a function of current and frequency.
- If current is increased:
  - more powerful sparks are generated.
  - more material is removed per unit time.
  - larger craters are generated.
  - a rougher finish is produced.
  - If current is decreased, the opposite occurs.
  - However, it is more time consuming.

EDM Parameters

- Frequency
  - Increasing/decreasing frequency has little effect on the MRR (while keeping current constant).
  - MRR is directly proportional to current.
- Increasing frequency:
  - means less power for each spark.
  - less material is removed by each.
  - a smoother surface can be achieved.
  - however, it is more time consuming.

EDM Tooling

- Electrodes are made of graphite or other alloys.
- Can make electrodes by machining, forming, casting.
- Can make very small and deep holes (dia. 0.005") ratio as large as 400:1.
- Tool wears as it erodes; graphite electrodes have greatest wear resistance.
- Must make multiple electrodes to cut the same cavity to compensate for wear.

EDM Capabilities

- Great for irregular shaped cavities.
- Can make sharp corners.
- MRR can be 2 - 400 mm^3/min, depending on material and parameters.
- Used for:
  - Die and mold cavities.
  - Small deep holes.
  - Multiple Intricate Shapes
  - Internal Cavities

EDM Machines

Wire EDM (WEDM)

- Process is similar to cutting with a band saw.
- Moving wire travels along specified path.
- Wire cuts workpiece by discharging sparks.
- Dielectric floods the spark region, carrying away debris.
- Can cut plates 12" thick.
- When doing inside cuts, must have previous pilot hole to thread wire.

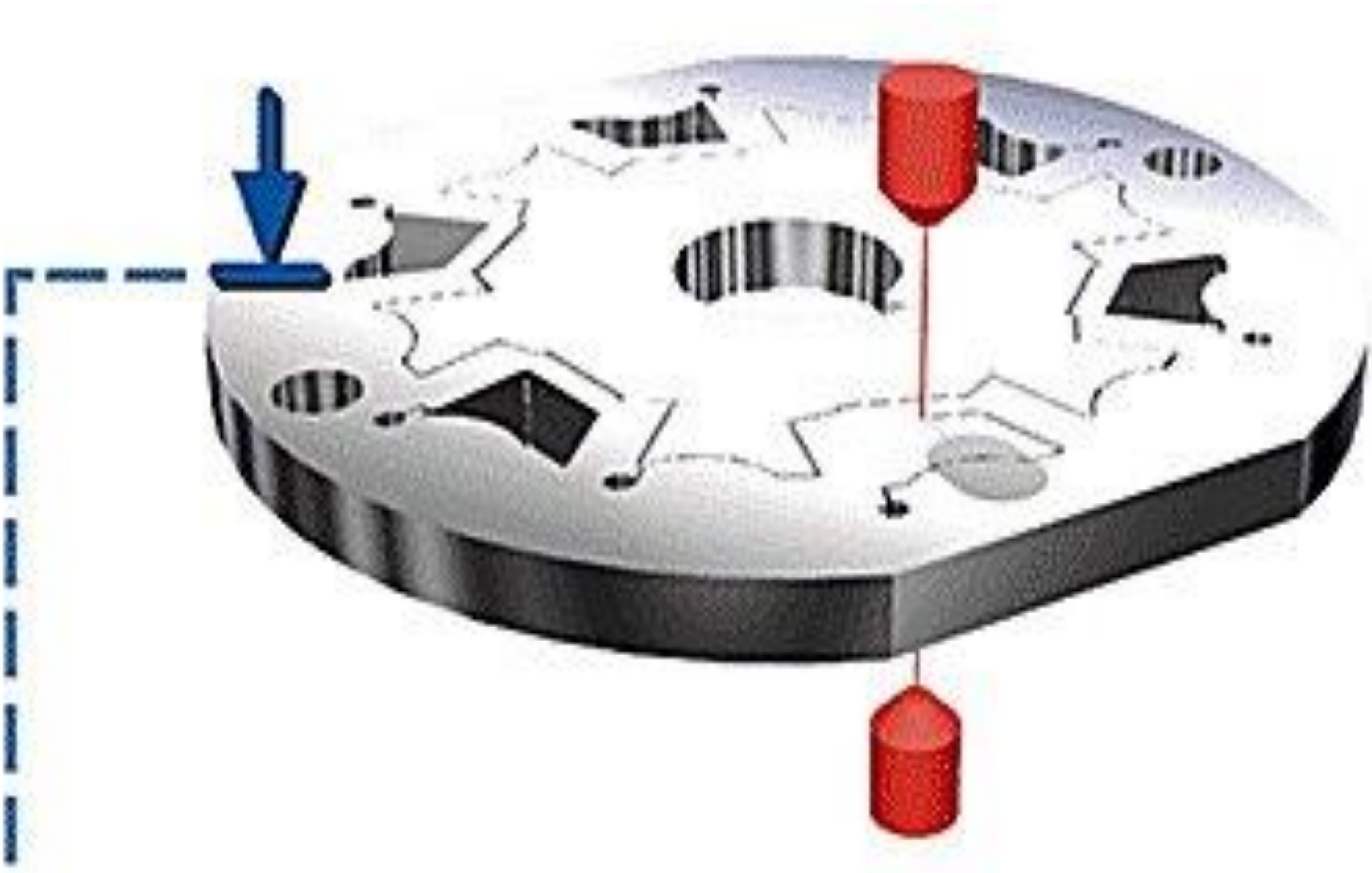
WEDM Tooling

- Wire
  - Made of brass, copper or tungsten.
  - Can be as thin as 0.005".
  - Must be strong and tough.
  - Used only once, but cheap.
  - Kerf: gap left by wire on material after cutting.

  - Typical wire velocity: 0.15-9 m/min.
  - Cutting Speed: 6 mm/min for steel.

WEDM Machine

Wire EDM Example



Laser Beam Machining (LBM)

- Source of energy is laser: highly focused, high density energy beam.
- Most common Laser types:
  - CO_2 (Carbon-dioxide lasers are the highest-power continuous-wave lasers that are currently available. They are also quite efficient: the ratio of output power to pump power can be as large as 20%. produces a beam of infrared light with the principal wavelength bands centering on 9.6 and 10.6 micrometers (μm))
  - Nd:YAG (Nd:YAG (neodymium-doped yttrium aluminum garnet; Nd:Y3Al5O12) is a crystal that is used as a lasing medium for solid-state lasers. Nd:YAG lasers typically emit light with a wavelength of 1064 nm, in the infrared)
- Can be pulsed or continuous wave.

Laser Beam Machining (LBM)

- Important Physical parameters of workpiece:
  (the lower the better)
  - Reflectivity
  - Thermal conductivity
  - Specific Heat
  - Latent heats of melting/evaporation

Laser Beam Machining (LBM)

Laser Beam Machining (LBM)

- Process Capabilities
  - Drilling (as small as 0.0002")
  - Cutting of Metals, non-metals, ceramics, composites (as thick as 1.25")
  - Very flexible: can compete with sheet metal cutting with traditional punching processes.




Laser Beam Machining (LBM)

- Other Uses:

  Welding

  Localized Heat Treating

  Marking,engraving of parts.
- Design Considerations

  Use on dull, unpolished surfaces.

  Avoid sharp corners. Deep cuts produce tapers.

IV. Chemical Machining (CHM)

Material removal through contact with a strong chemical etchant

- Processes include:
  - Chemical milling
  - Chemical blanking
  - Chemical engraving
  - Photochemical machining
- All utilize the same mechanism of material removal

Chemical Machining (CM)

- Chemicals can attach and *etch* metals.
- Etching removes small amounts of material from surface.
- Reagents/etchants are typically acid/alkaline solutions.
- Used in the past for engraving.

Chemical Machining (CM)

- Can produce shallow cavities on sheets, plates up to 0.5".
- Main purpose: weight reduction.
- Can selectively attack regions of the material via:
  - masking
  - partial immersion

<u>Chemical Machining Procedure </u>(I)

- Stress-relieve the part to prevent post-CM warping.
- Thoroughly clean/degrease part

  (to ensure good mask adherence & material removal.)
- Apply masking material to entire part.
- Remove masking material from regions to be etched.

Chemical Machining Procedure (II)

- Expose material to etchants (i.e. NaOH, HNO_3) while controlling temperature, stirring and time.
- Wash part thoroughly.
- Remove masking material, clean part, inspect.

Chemical Blanking (CB)

- Blanking consists in producing shapes that fully penetrate the thickness of the material.
- Chemical blanking is done via chemical dissolution rather than shearing.
- No burrs are left.
- Can blank complex, small or decorative shapes on thin metal.

Photo Chemical Blanking (PCB)

- A variation of chemical milling.
- Material is removed via photographic techniques.
- Can create shapes on metal as thin as 0.0001".

PCB Procedure (I)

- Prepare a design to be blanked, magnified up to 100X.
- Make a negative and reduce to part scale (the artwork).
- Coat sheet blank with photoresist (dip, spray, coat and oven dry).
  - Coat is called emulsion.

PCB Procedure (II)

- Place negative over coated blank and expose to UV light, hardening exposed areas.
- Develop blank to dissolve unexposed areas.
- Immerse blank in reagent to etch away exposed areas.
- Remove masking and wash thoroughly.

PCB Considerations

- Etchant attacks material in horizontal and vertical direction.
- Undercuts develop and must be taken into account.
- Must control environment to control size changes.
- Avoid designs with sharp corners, deep narrow cavities, seams tapers.