



INSTITUTE OF AERONAUTICAL ENGINEERING

(AUTONOMOUS)
DUNDIGAL, HYDERABAD – 500043

MECHANICAL ENGINEERING

UNCONVENTIONAL MACHINING PROCESS

Course Code: A70359 – JNTUH - R15

Prepared By,

S. Srikrishnan
Assistant Professor

UNIT I

- Introduction: Need for non-traditional machining methods- Classification of modern machining processes- considerations in process selection. Materials, applications.
- Ultrasonic machining – elements of the process, mechanics of metal removal process parameters, economic considerations, applications and limitations, recent development.

UNCONVENTIONAL MACHINING AND THERMAL CUTTING PROCESSES

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

Unconventional 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

Why Unconventional 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

Classification of Unconventional 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 work part, while other portions are protected by a mask

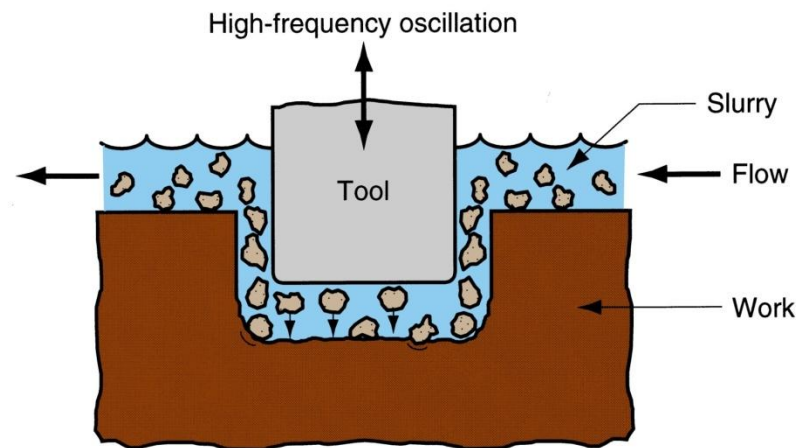
I. Mechanical Energy Processes

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

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

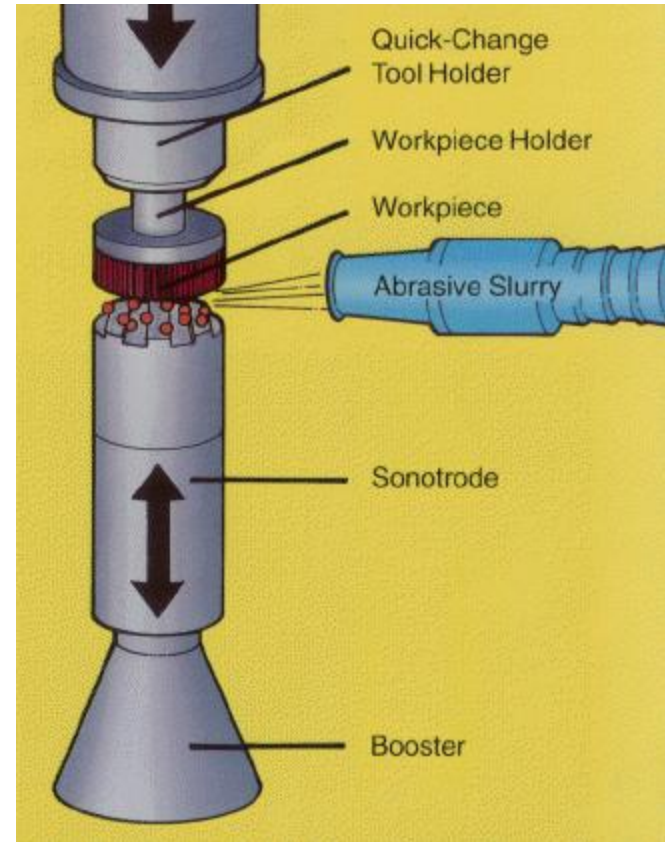
- Tool oscillation is perpendicular to work surface
- Tool is fed slowly into work
- Shape of tool is





Ultrasonic Machining

- Ultrasonic vibration (20,000 Hz) of very small amplitudes (0.04-0.08 mm) drive the form tool (sonotrode) of ductile material (usually soft steel)
- An abrasive slurry is flowed through the work area
- The workpiece is brittle in nature (i.e. glass)
- The workpiece is gradually eroded away.



USM Applications

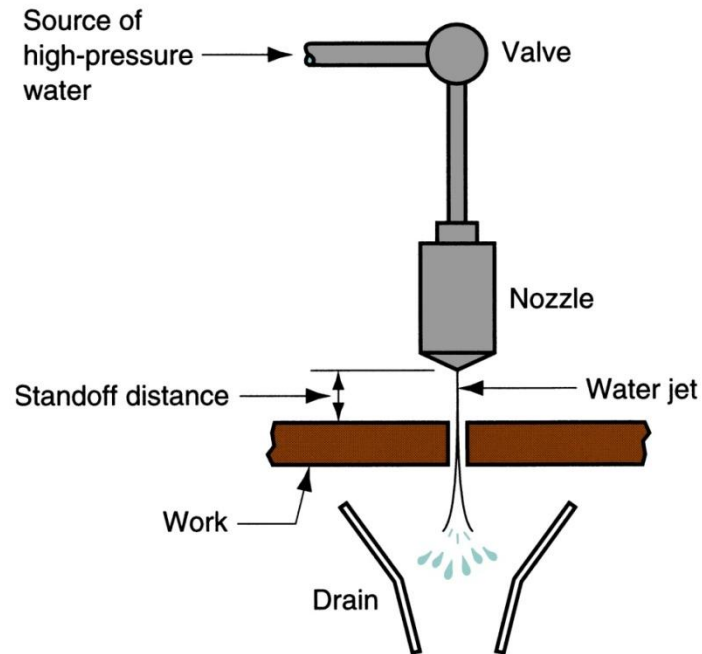
- Hard, brittle work materials such as ceramics, glass, and carbides
- Also successful on certain metals, such as stainless steel and titanium
- Shapes include non-round holes, holes along a curved axis
- “Coining operations” - pattern on tool is imparted to a flat work surface

UNIT II

- Abrasive jet machining, water jet machining and abrasive water jet machine: Basic principles, equipment's, process variables, mechanics of metal removal, MRR, application and limitations.
- Electro-Chemical Processes: Fundamentals of electro-chemical machining, electro-chemical grinding, electro chemical honing and deburring process, metal removal rate in ECM, Tool design, Surface finish and accuracy economic aspects of ECM-Simple problems for estimation of metal removal rate.

Water Jet Cutting (WJC)

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



WJC Applications

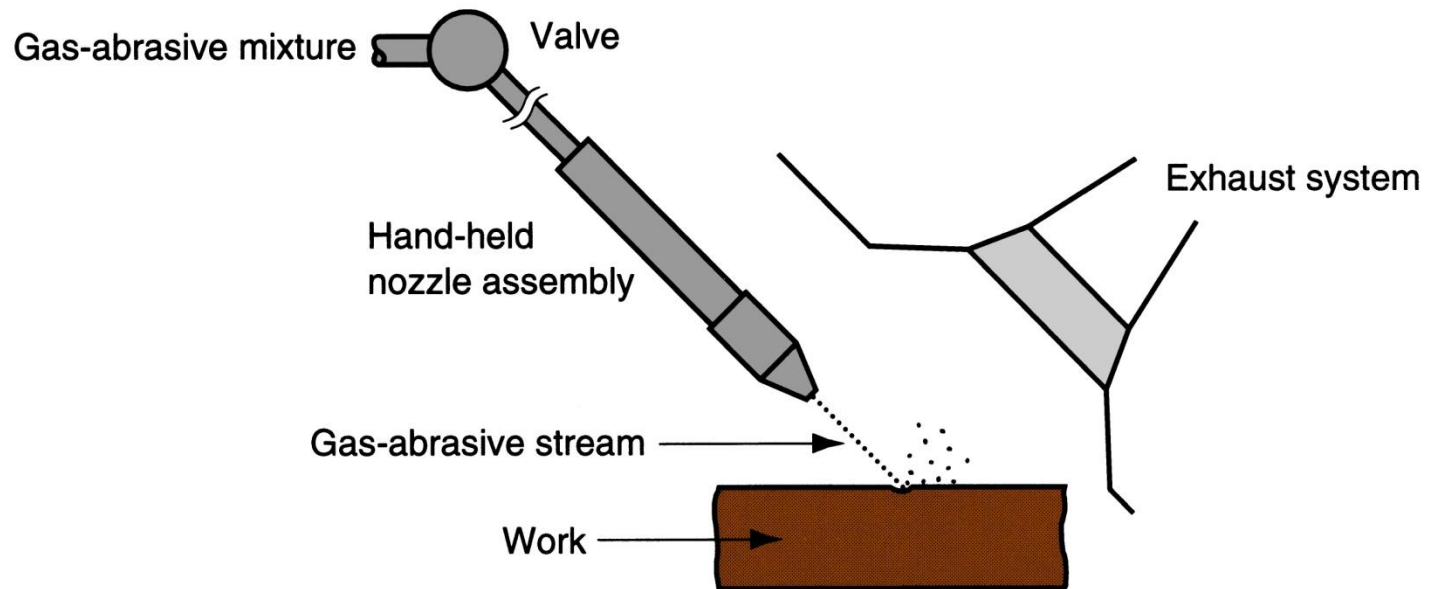
- Usually automated by CNC or industrial robots to manipulate nozzle along desired trajectory
- Used to cut narrow slits in flat stock such as plastic, textiles, composites, floor tile, carpet, leather, and cardboard
- Not suitable for brittle materials (e.g., glass)
- WJC advantages: no crushing or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

Abrasive Water Jet Cutting (AWJC)

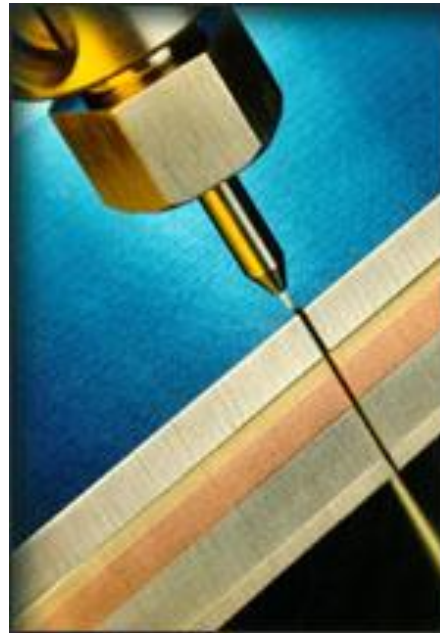
- When WJC is used on metals, abrasive particles must be added to jet stream usually
- Additional process parameters: abrasive type, grit size, and flow rate
 - Abrasives: aluminum oxide, silicon dioxide, and garnet (a silicate mineral)
 - Grit sizes range between 60 and 120
 - Grits added to water stream at about 0.25 kg/min (0.5 lb/min) after it exits nozzle

Abrasive Jet Machining (AJM)

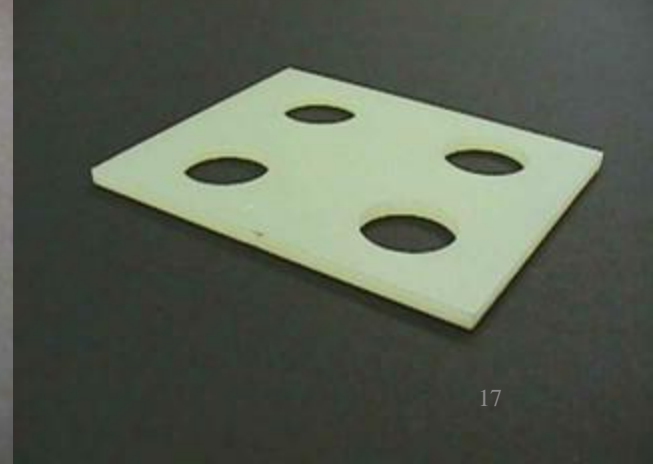
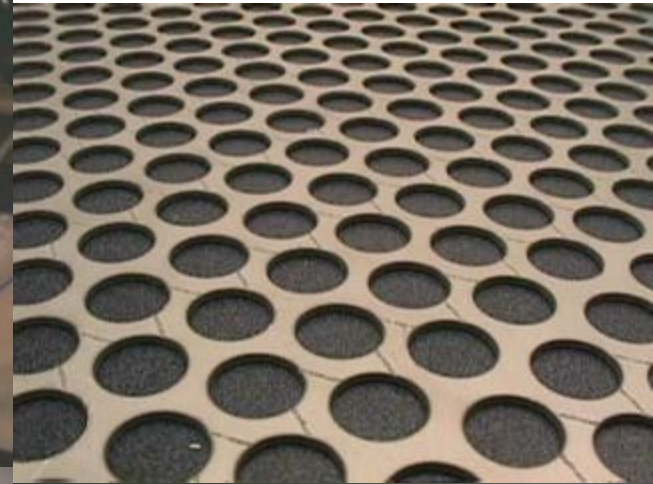
- High velocity stream of gas containing small abrasive particles



Waterjet and Abrasive Waterjet (AWJ) Cutting

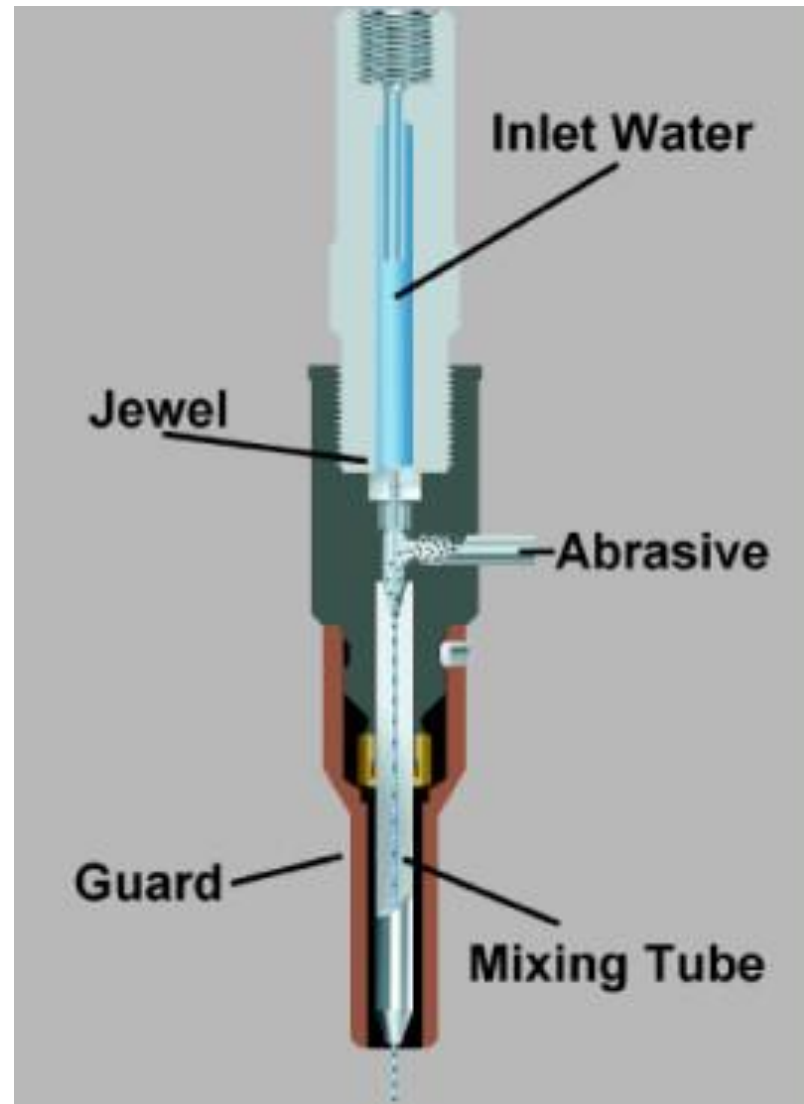


*Abrasive
Waterjet and
Waterjet
examples*



Abrasive Water Jet

- High pressure water (20,000-60,000 psi)
- Educt abrasive into stream
- Can cut extremely thick parts (5-10 inches possible)
 - Thickness achievable is a function of speed
 - Twice as thick will take more than twice as long
- Tight tolerances achievable
 - Current machines 0.002" (older machines much less capable ~ 0.010")
- Jet will lag machine position, so controls must plan for it



AJM Application Notes

- Usually performed manually by operator who directs nozzle
- Normally used as a finishing process rather than cutting process
- Applications: deburring, trimming and deflashing, cleaning, and polishing
- Work materials: thin flat stock of hard, brittle materials (e.g., glass, silicon, mica, ceramics)

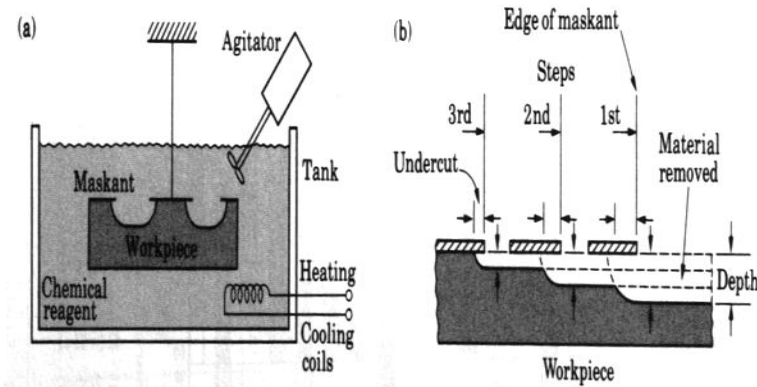
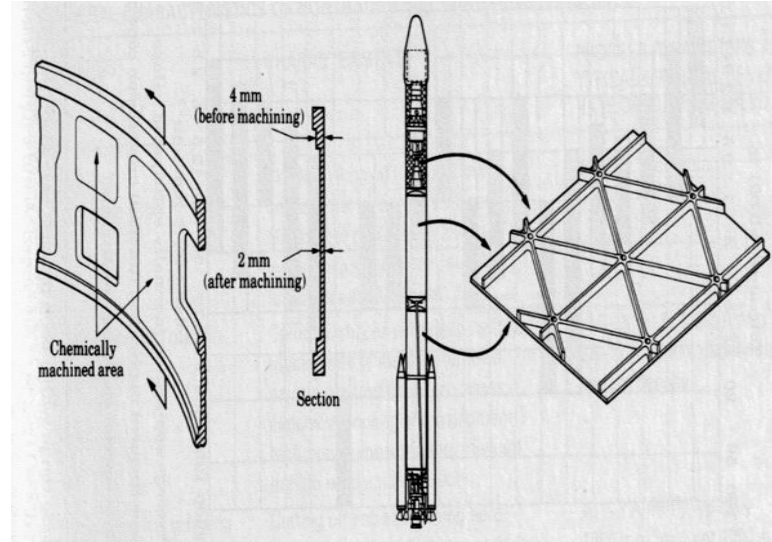
IV. Chemical Machining (CHM)

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

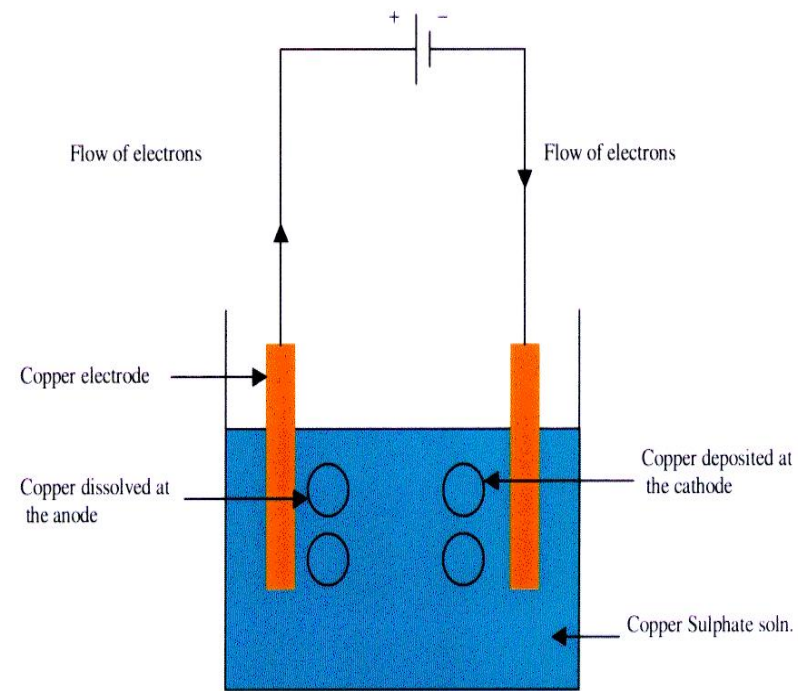
Chemical Machining (Chemilling)

- Applications:
 - Aerospace industry
 - Engraving
 - Circuit boards
- A maskant is applied over areas you don't want to machine
 - Photochemical methods
 - Apply maskant to entire surface and use laser to cut
- Place the entire part in a chemical bath (acid or alkali depending upon the metal)
- Control temperature and time of exposure to control material removal



Electro-Chemical Machining (ECM)

- Works on the principle of electrolysis – accelerated chemilling
- Die is progressively lowered into workpiece as workpiece is dissociated into ions by electrolysis
- Electrolytic fluid flows around workpiece to remove ions and maintain electrical current path
- Low DC voltage, very High current (700 amps)



Electrochemical grinding

- Combines electrochemical machining with conventional grinding
 - Grinding wheel is the cathode
 - Metal bonded wheel with diamond or Al_2O_3 abrasive
 - Majority of material removal from electrolytic action (95%) therefore very low wheel wear
 - Much faster than conventional grinding

UNIT III

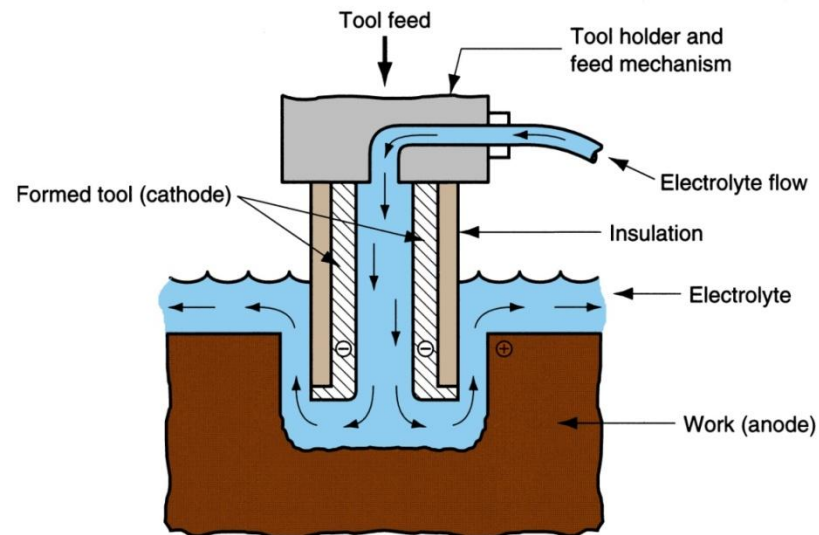
- Thermal Metal Removal Processes: General Principle and applications of Electric Discharge Machining, Electric Discharge Grinding and electric discharge wire cutting processes-Power circuits for EDM, Mechanics of metal removal in EDM, Process parameters, selection of tool electrode and dielectric fluids, surface finish and machining accuracy, characteristics of spark eroded surface and machine tool selection. Wire EDM-principle and applications.

II. Electrochemical Machining Processes

- Electrical energy used in combination with chemical reactions to remove material
- Reverse of electroplating
- Work material must be a conductor
- Processes:
 - Electrochemical machining (ECM)
 - Electrochemical deburring (ECD)
 - Electrochemical grinding (ECG)

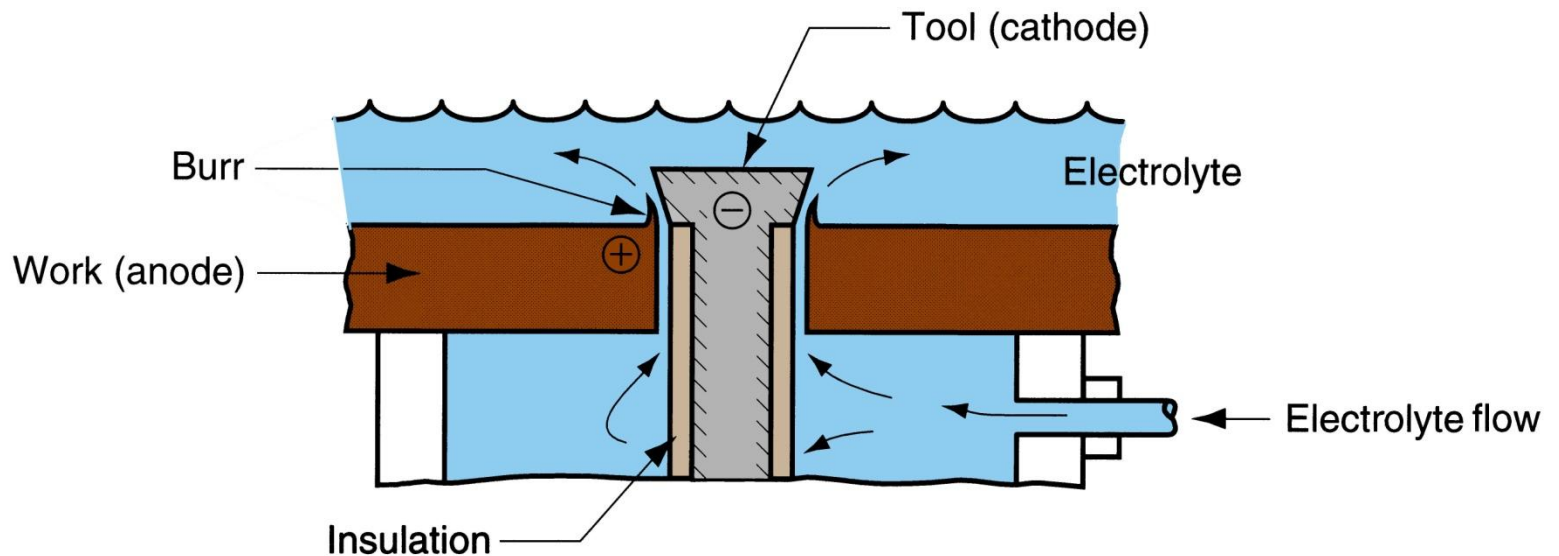
Electrochemical Machining (ECM)

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



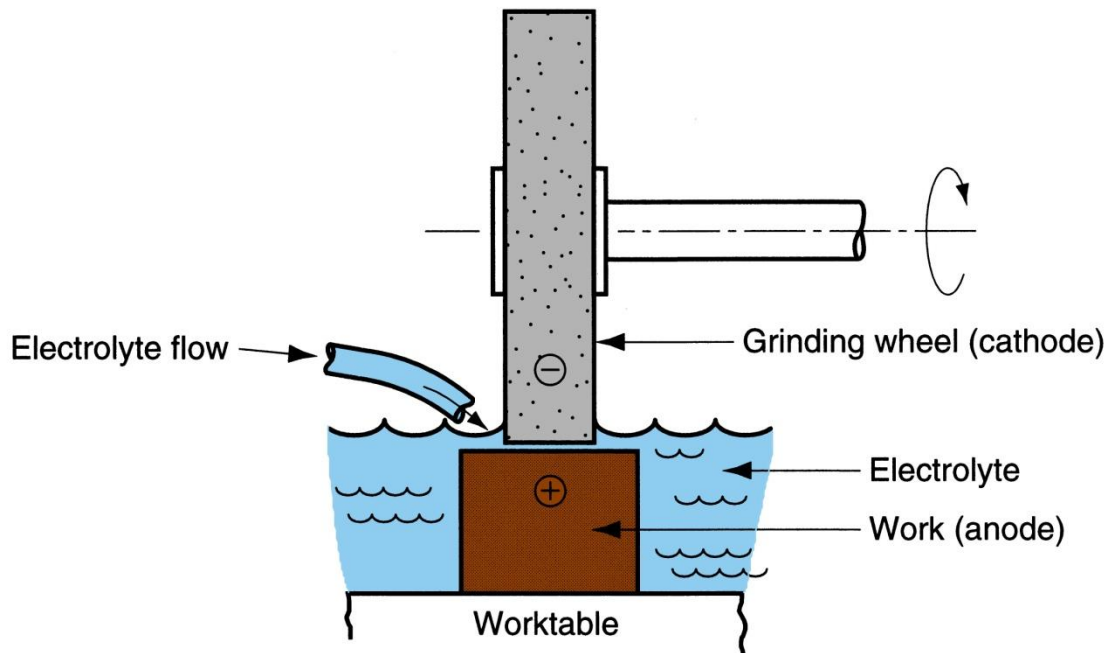
Electrochemical Deburring (ECD)

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



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

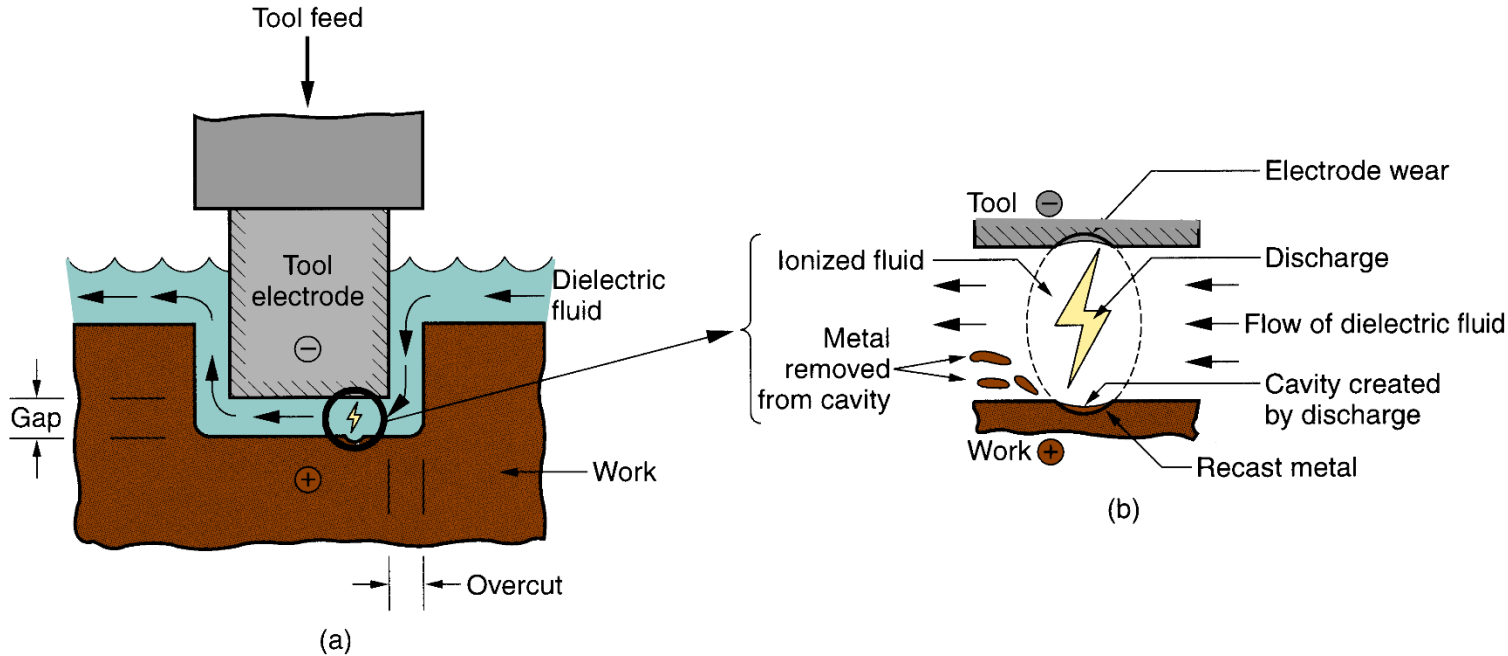
- Electric discharge machining
- Electric discharge wire cutting
- Electron beam machining
- Laser beam machining
- Plasma arc machining

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)



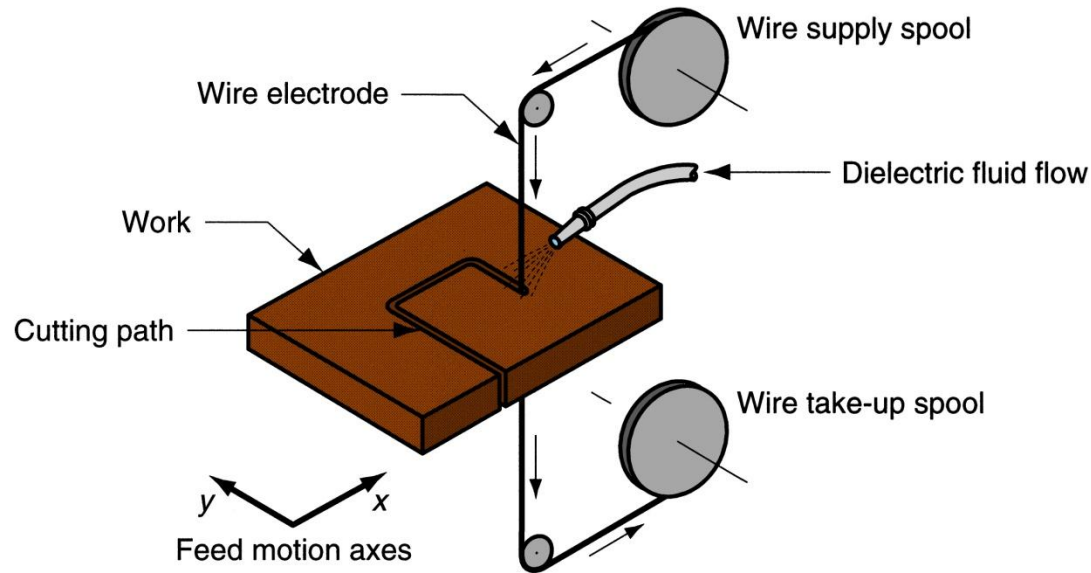
Electric discharge machining (EDM): (a) overall setup, and (b) close-up view of gap, showing discharge and metal removal

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

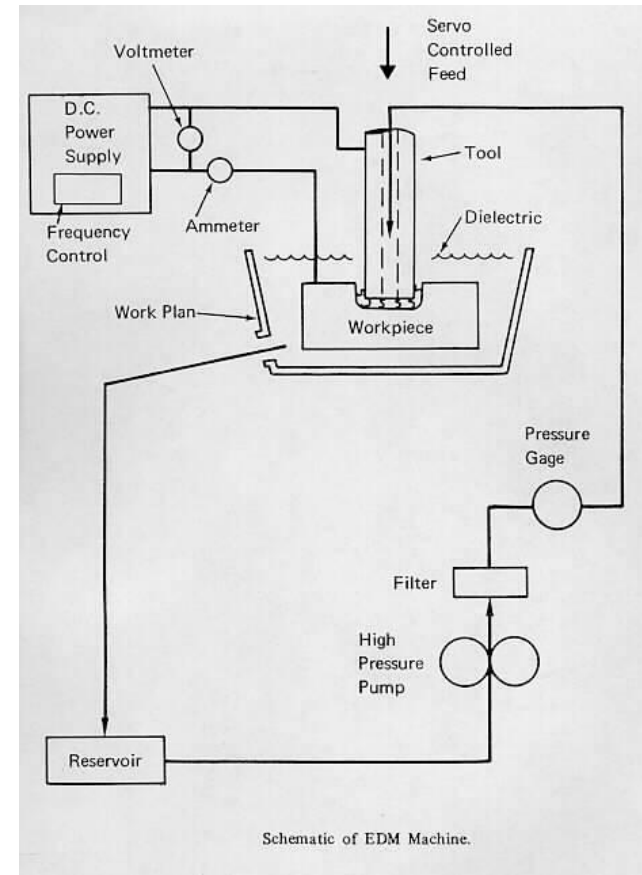
Special form of EDM that uses small diameter wire as electrode to cut a narrow kerf in work



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

Electrode Discharge Machining (EDM)

- Direct Competitor of ECM – much more common than ECM
- The tool acts as a cathode (typically graphite) is immersed in a Dielectric fluid with conductive workpiece
- DC voltage ($\sim 300V$) is applied. As voltage builds up over gap between workpiece and tool, eventually you get dielectric breakdown (sparking at around $12,000 \text{ deg F}$)
- The sparking erodes the workpiece in the shape of the tool
- The tool is progressively lowered by CNC as the workpiece erodes
- Cycle is repeated at $200,000\text{-}500,000 \text{ Hz}$
- Dielectric:
 - Cools tool and workpiece
 - Flushes out debris from work area



Die Sinker vs. Wire EDM



- Die sinker EDM
 - The die sinks into the part as it sparks away the workpiece
 - Most common Injection molding die process
- Wire EDM
 - The electrode is a wire that traverses through the part
 - Common for Extrusion Dies

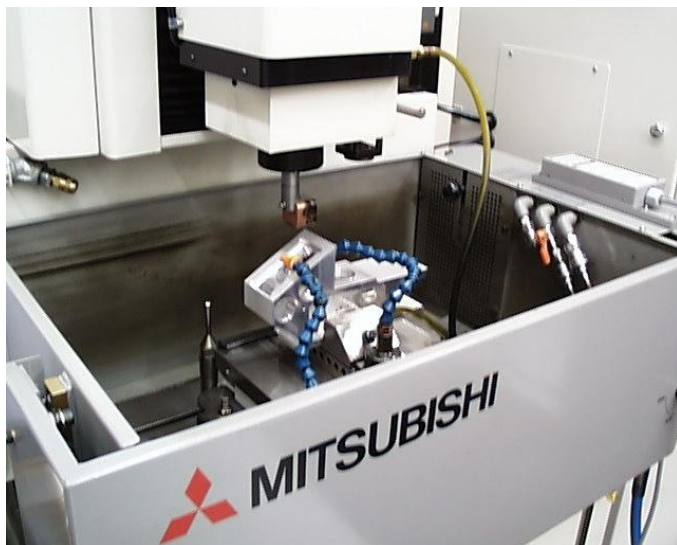
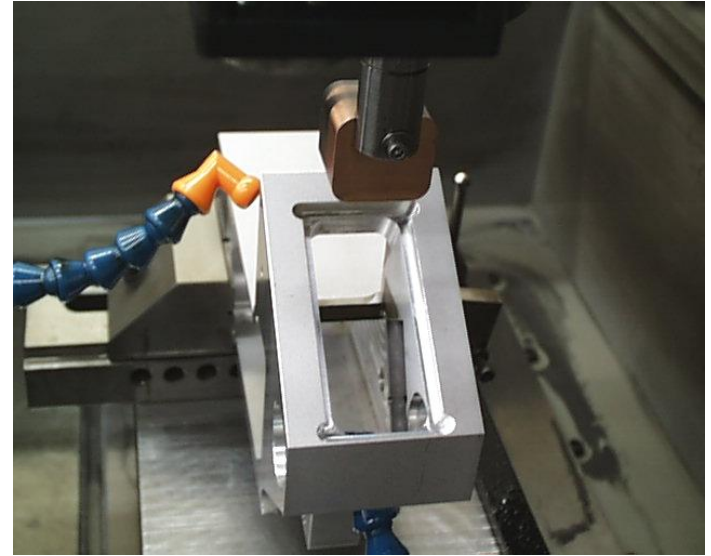
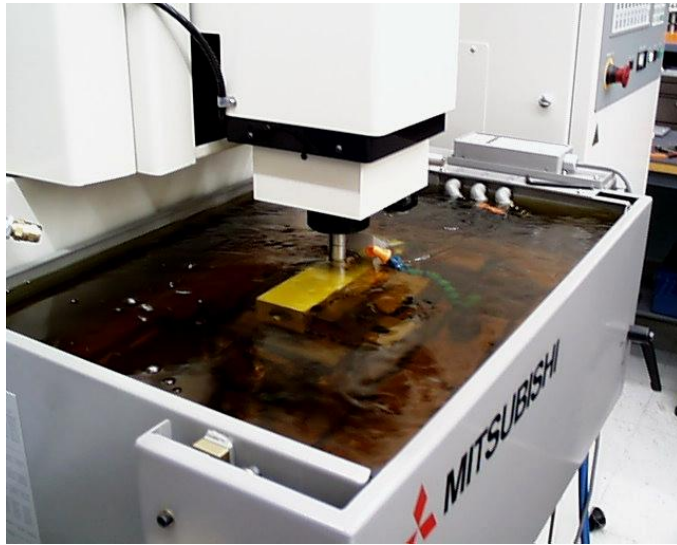


Case Study

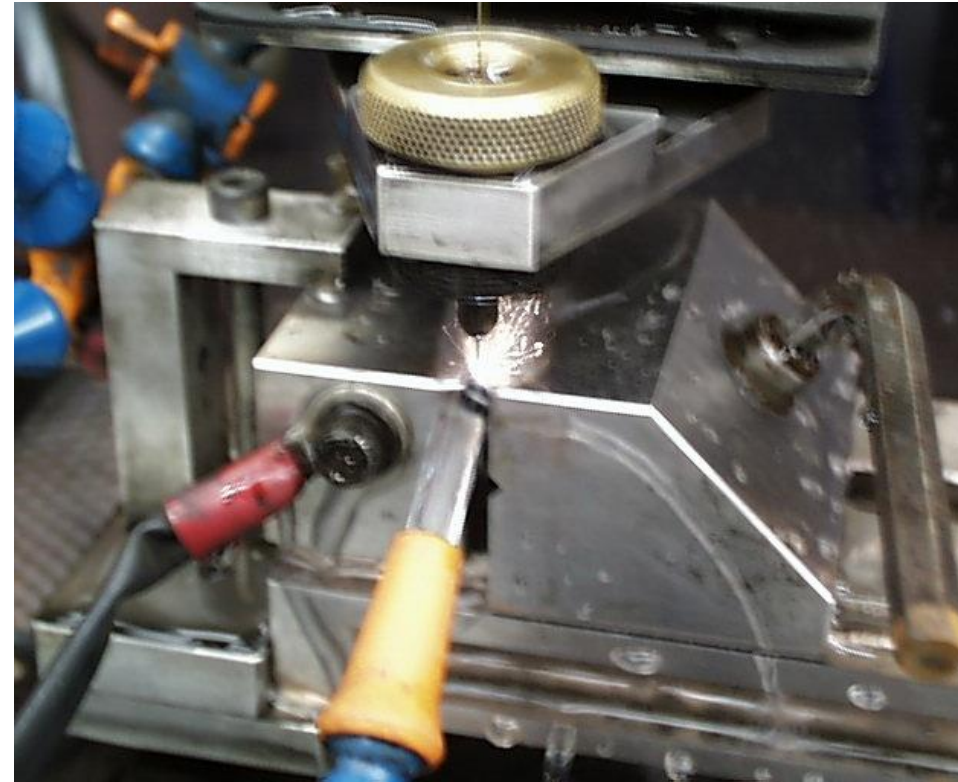
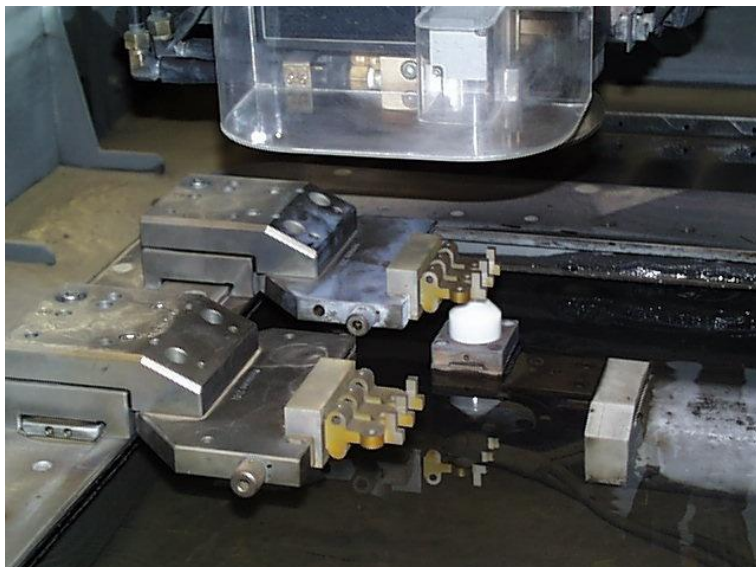
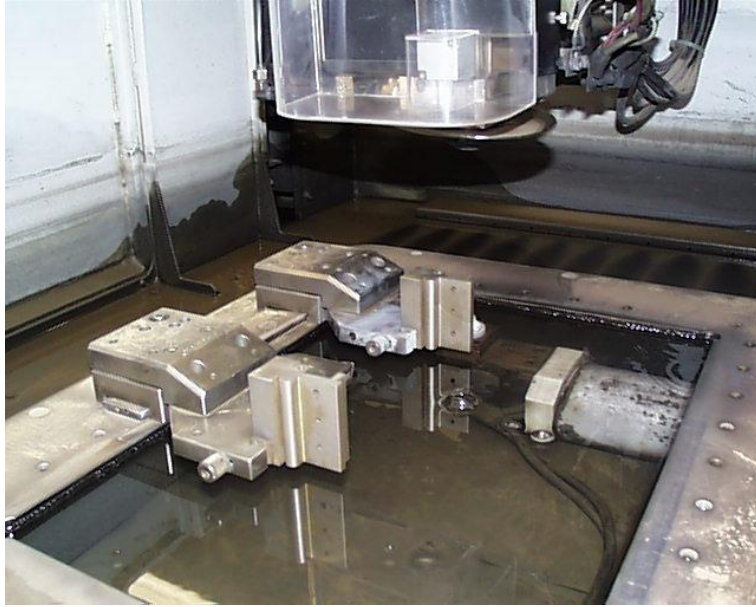
- CNC Mill
- CNC Wire EDM
- CNC EDM



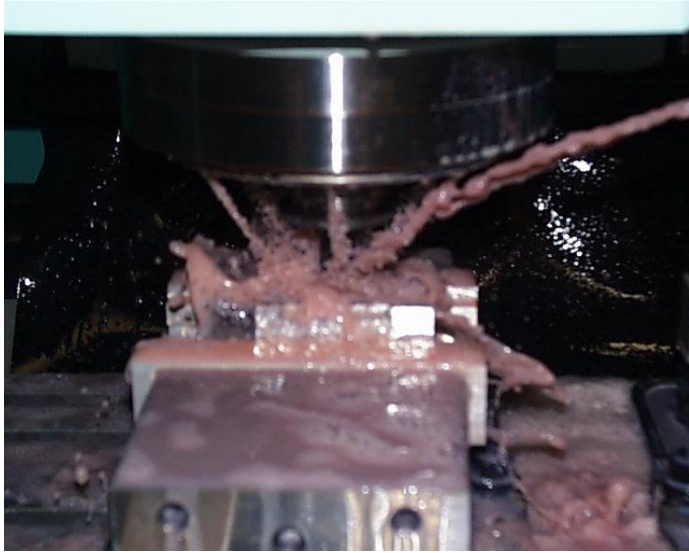
Wire EDM (not shown), Die Sinker EDM, Anodized



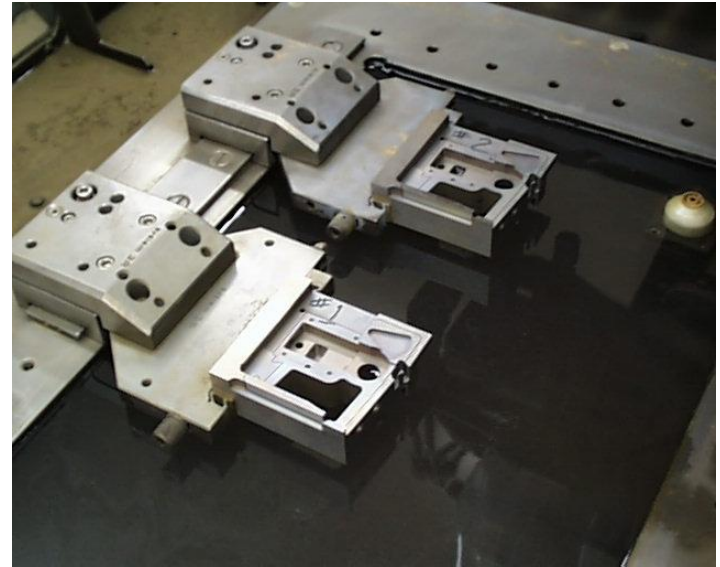
Different Part - Wire EDM – profiling and drilling



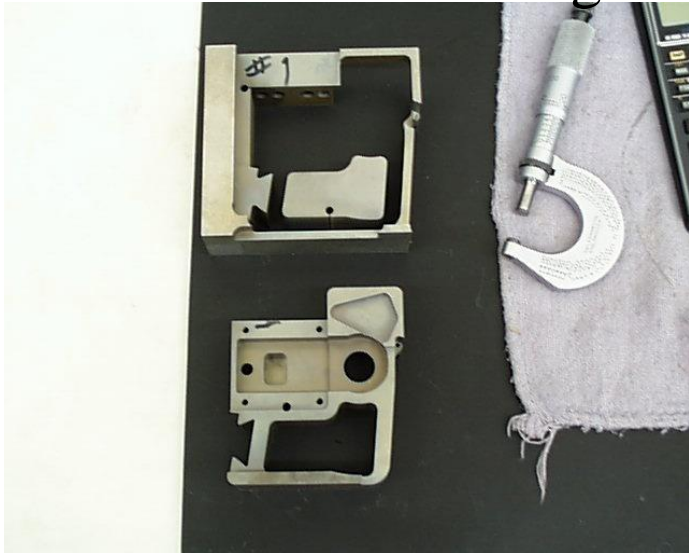
Case Study Three



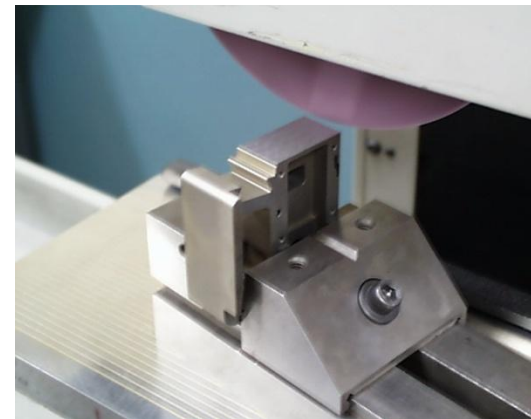
1. CNC Milling



2. Setup on wire EDM



3. QA After wire EDM

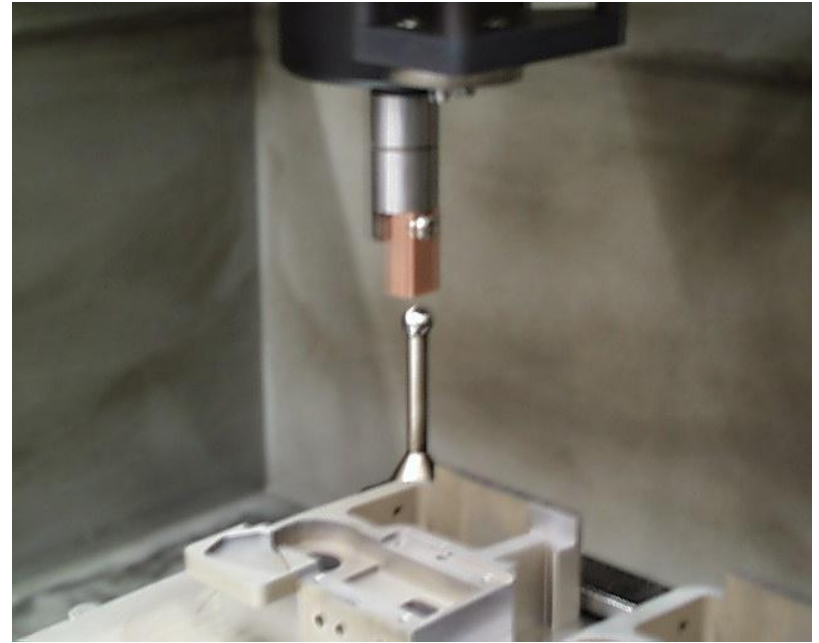


4. Grinding a face on the⁴⁰ part

Setup of Die Sinker EDM

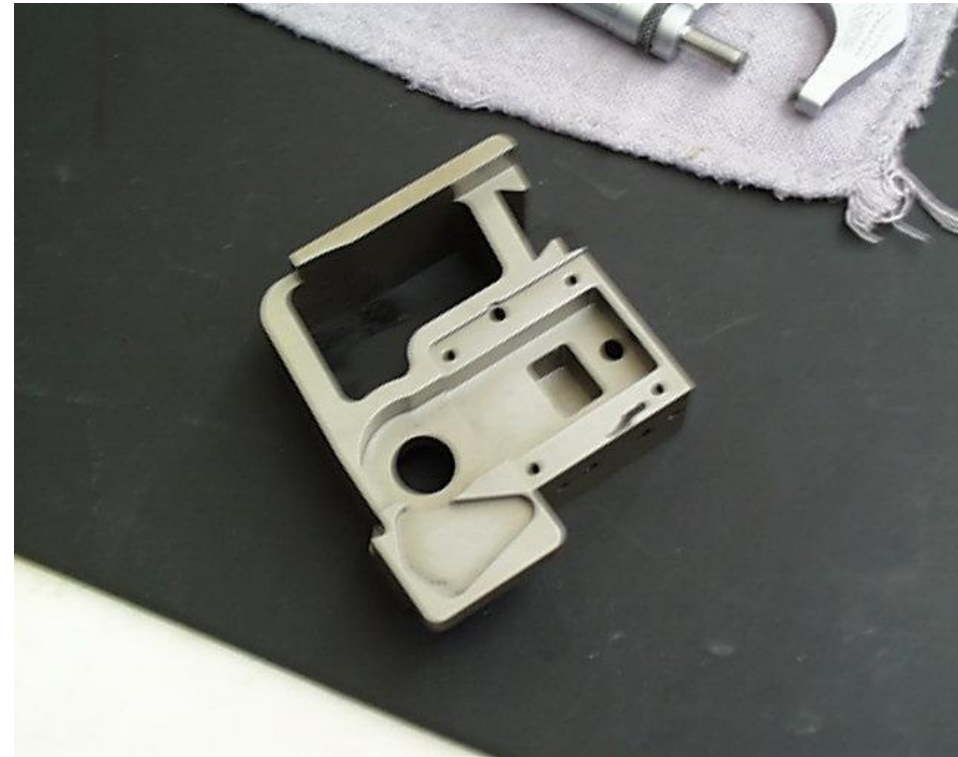
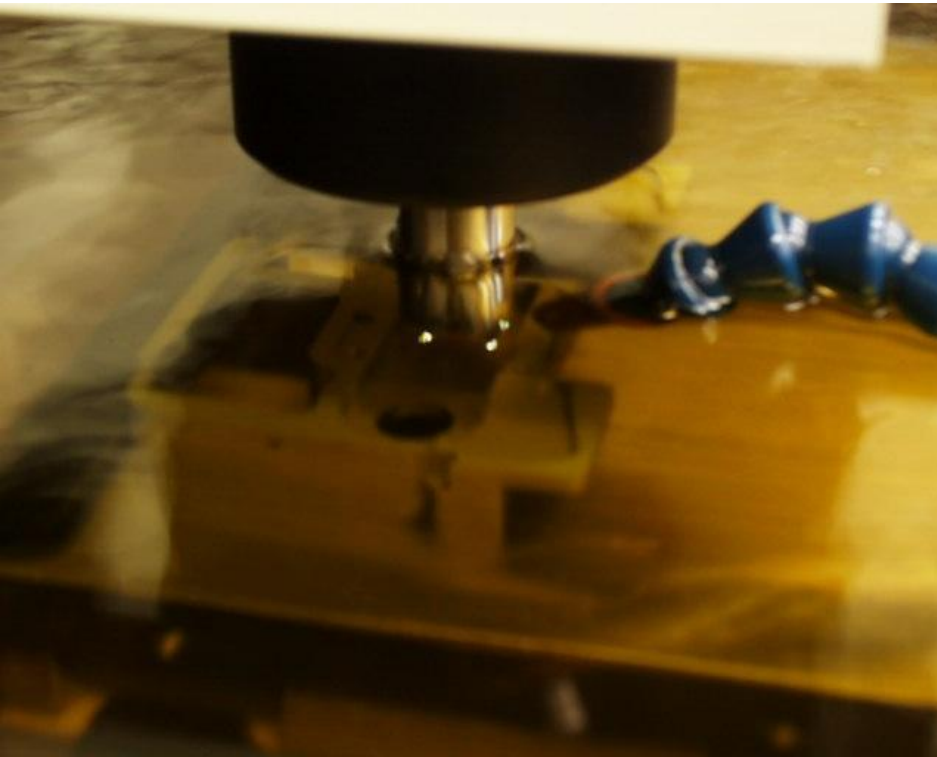


1. Locating parts relative to machine



2. Locating the electrode relative to parts setup

Die Sinker in action and finished product

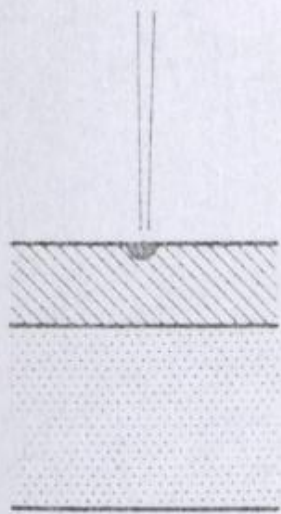


UNIT IV

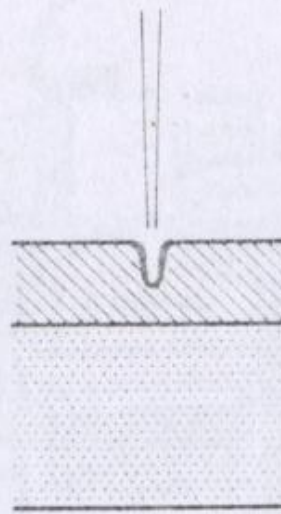
- Generation and control of electron beam for machining, theory of electron beam machining, comparison of thermal and non-thermal processes- General Principle and application of laser beam machining-thermal features, cutting speed and accuracy of cut.

Principle

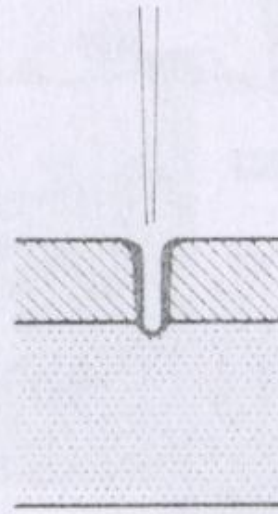
- A stream of high-speed electrons impinges on the work surface whereby the kinetic energy, transferred to the work material, produces intense heating. Depending on the intensity of the heat thus generated, the material can melt or vaporize



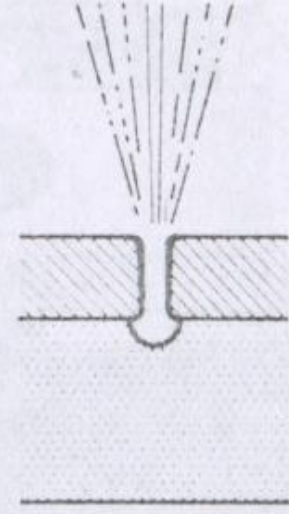
The sharply focused electron beam strikes the material to be drilled: local heating and fusion of the surface



The high power density of the electron beam produces a deepening metal vapour capillary encircled by molten material



The electron beam has drilled through the material being pierced and penetrates up to a certain depth into the auxiliary material



As a result of the high vapour pressure of the auxiliary material the molten part of the material being drilled is expelled

Figure 19.1 The four steps that lead to material removal by electron beam drilling (Source: courtesy, Messer Griesheim GmbH, Puchheim, W. Ger.).

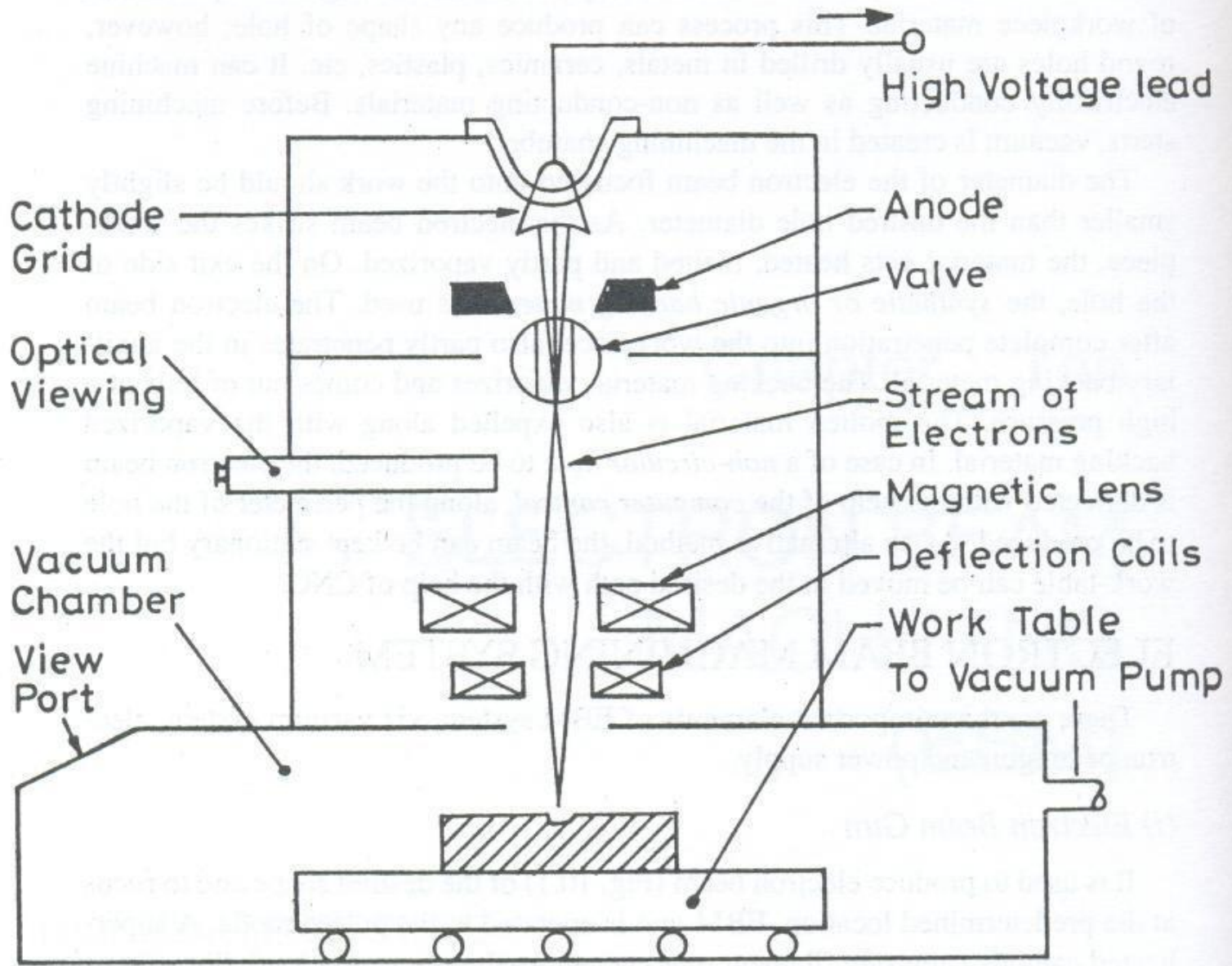
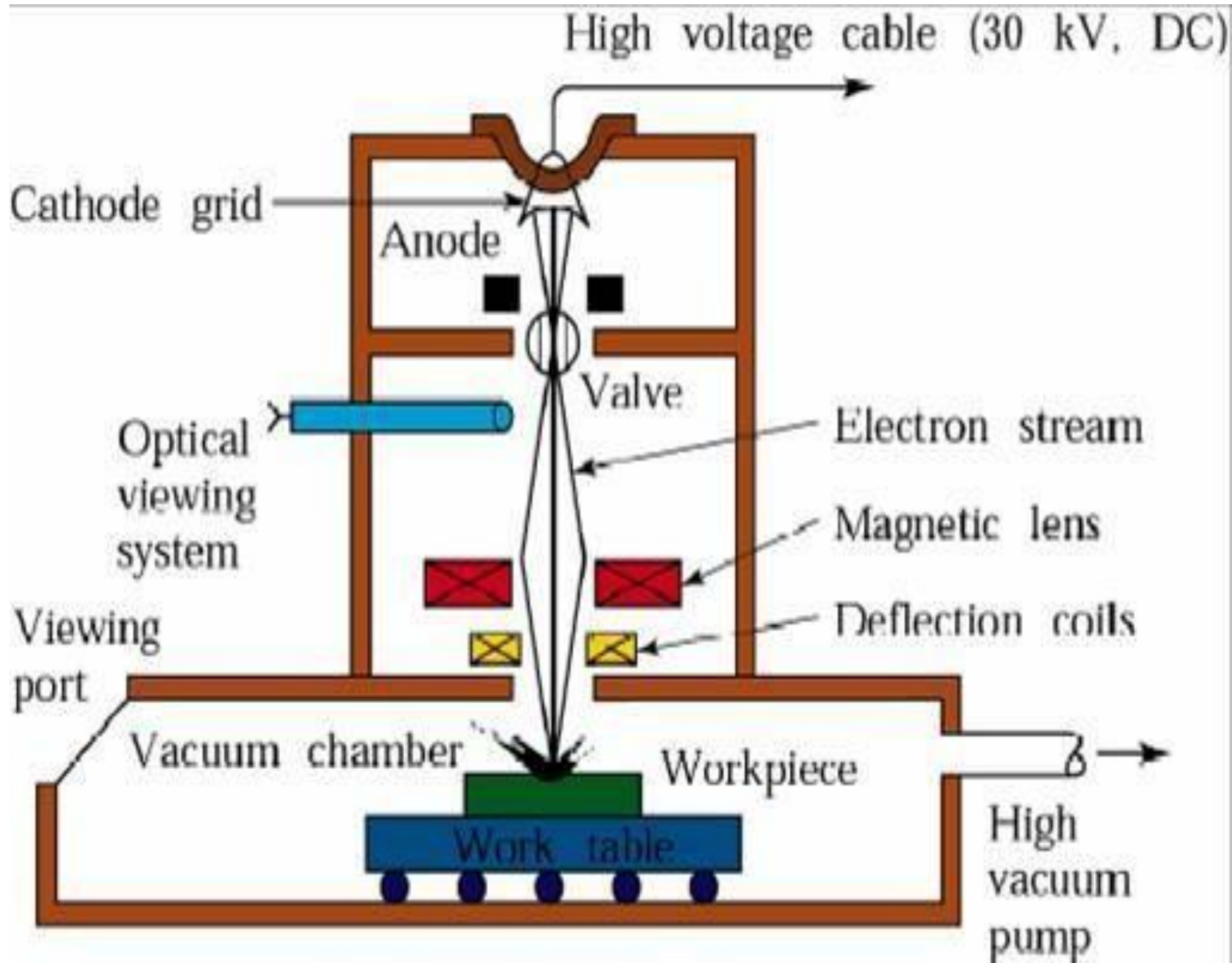
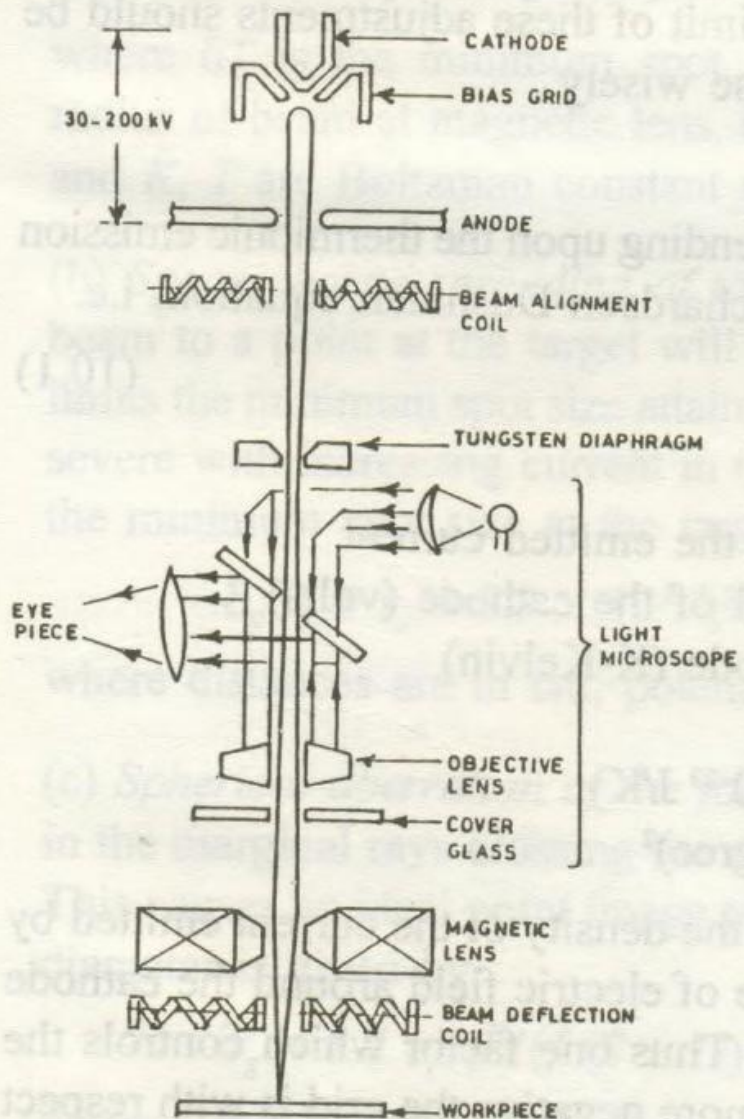
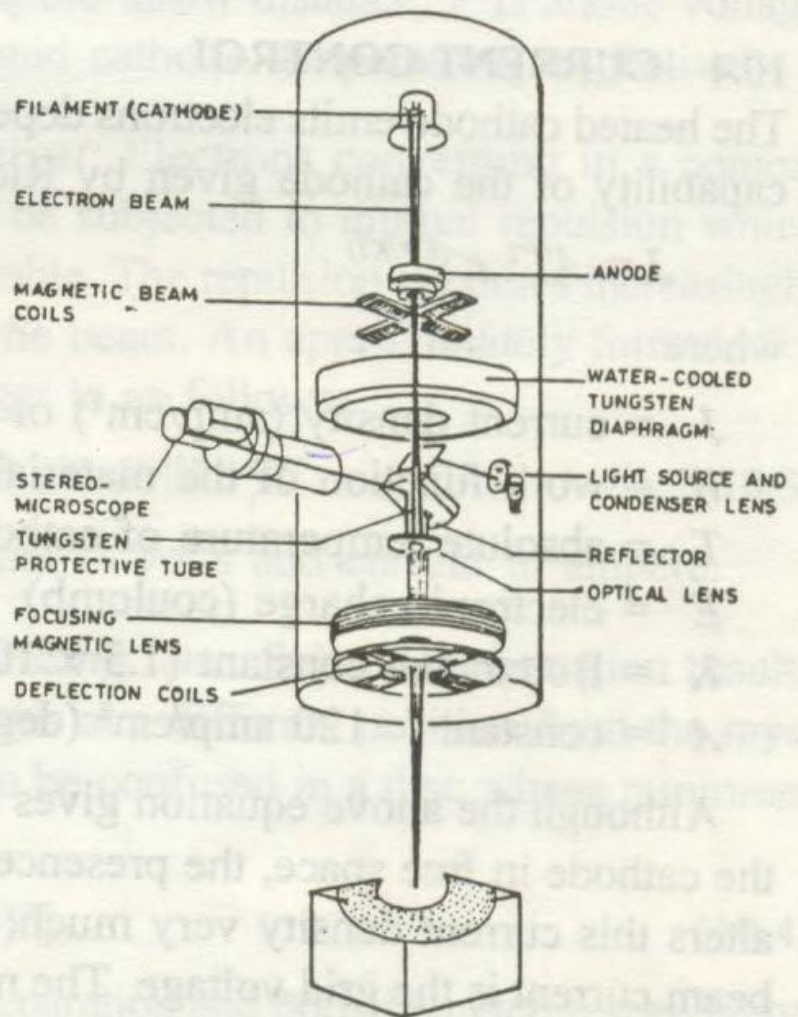


Fig. 10.1 Schematic diagram of electron beam machining system.





(a)



(b)

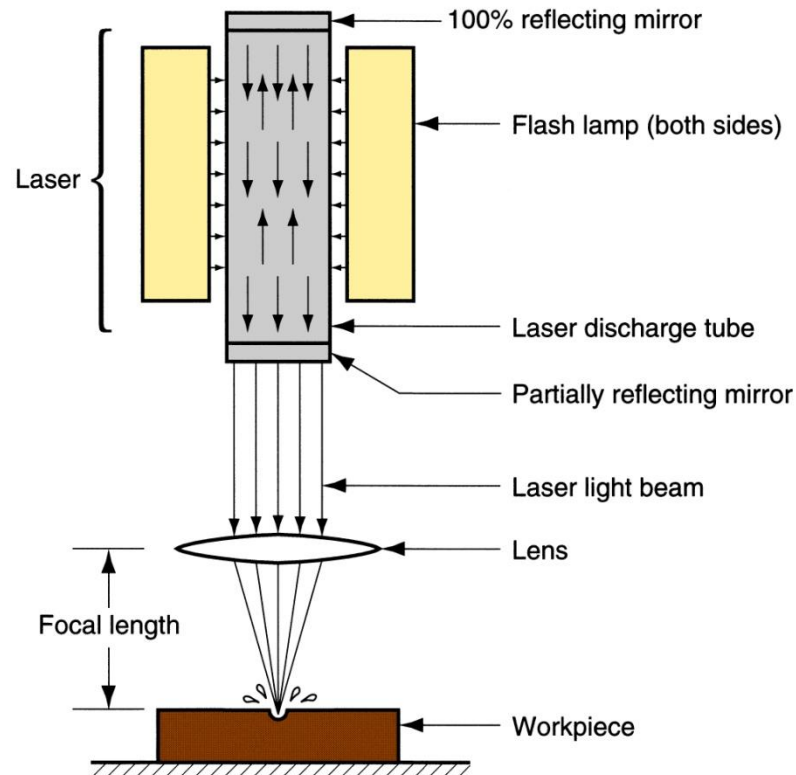
Fig. 10.1 Electron Beam Gun Construction Scheme

Laser Beam Machining

- Lasers are high intensity focused light sources
 - CO₂
 - Most widely used
 - Generally more powerful than YAG lasers
 - Cutting operations commonly
 - Nd:YAG (Neodymium ions in an Yttrium Aluminum Garnet)
 - Less powerful
 - Etching/marking type operations more commonly
- Limited in depth of cut (focus of light)
- Would limit workpiece to less than 1 inch (< ½" typically)

Laser Beam Machining (LBM)

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



UNIT V

- Application of plasma for machining, metal removal mechanism, process parameters, accuracy and surface finish and other applications of plasma in manufacturing industries. Chemical machining-principle- maskants-etchants-applications.

Principle

- When heated to elevated temperatures, gases turn into a distinctly different type of matter, which is plasma
- When gases are heated by an applied electric field, an igniter supplies the initial electrons, which accelerate in the field before colliding and ionizing the atoms. The free electrons, in turn, get accelerated and cause further ionization and heating of the gases. The avalanche continues till a steady state is obtained in which the rate of production of the free charges is balanced by recombination and loss of the free charges to the walls and electrodes.
- The actual heating of the gas takes place due to the energy liberated when free ions and electrons recombine into atoms or when atoms recombine into molecules

Typical plasma torch construction

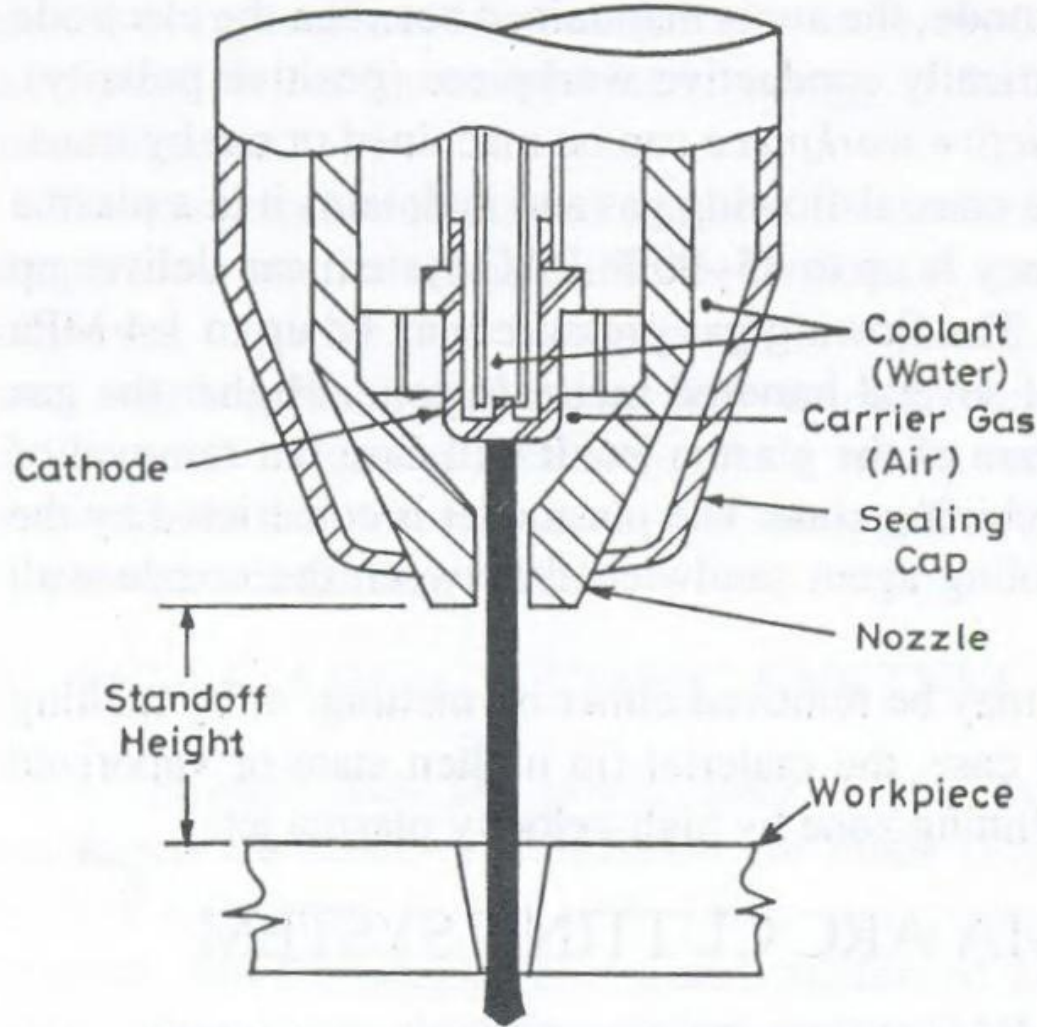
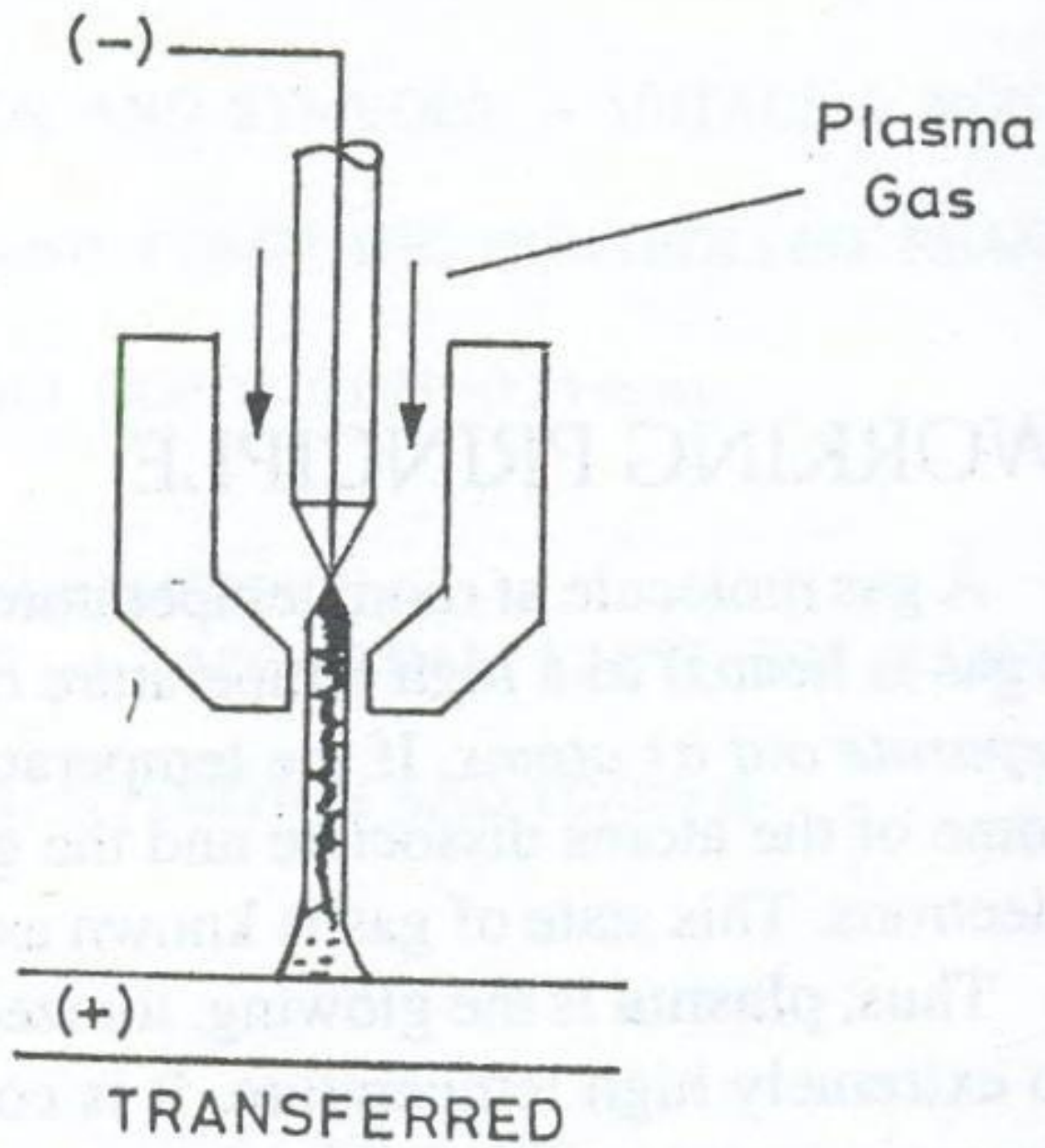
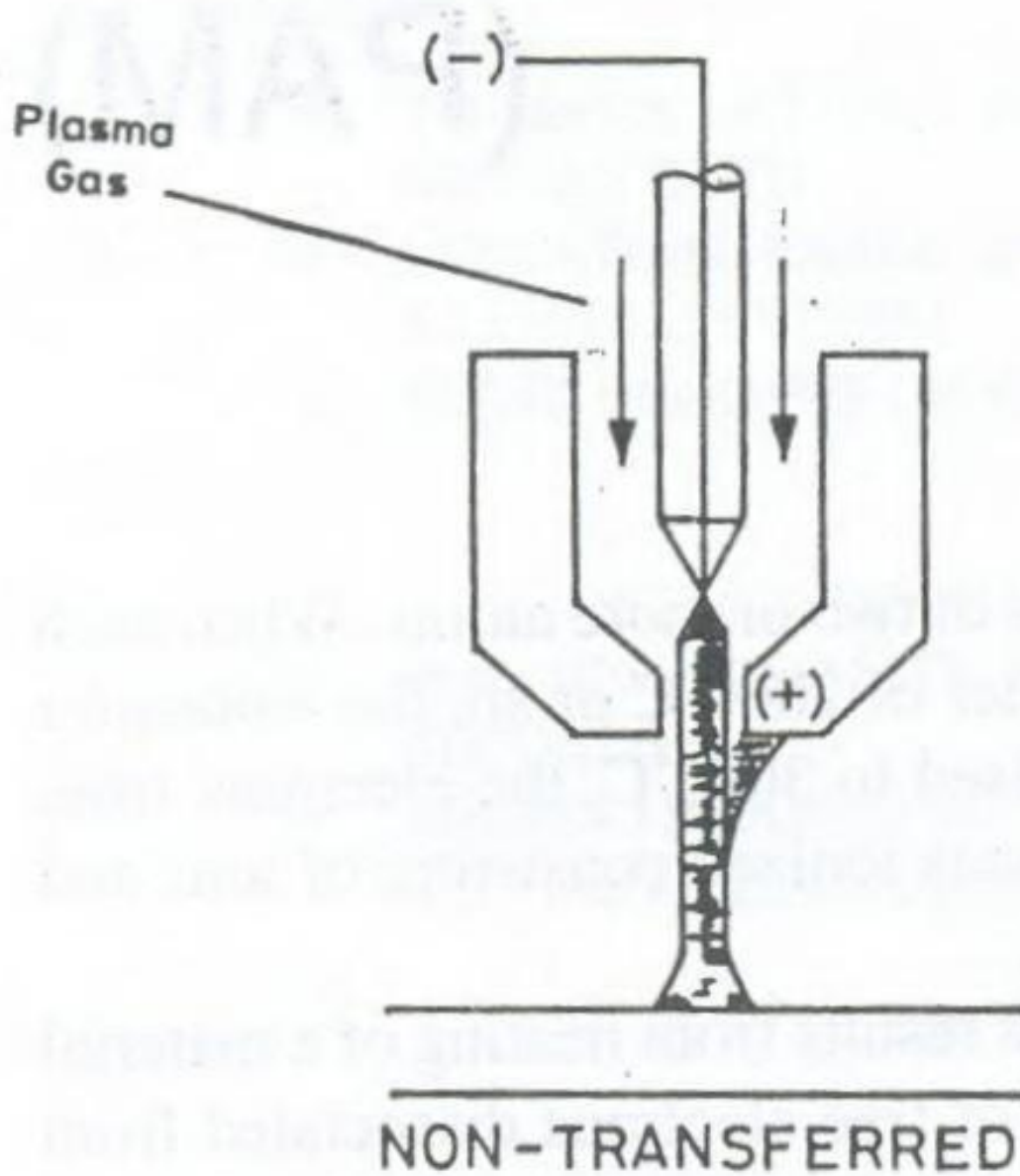


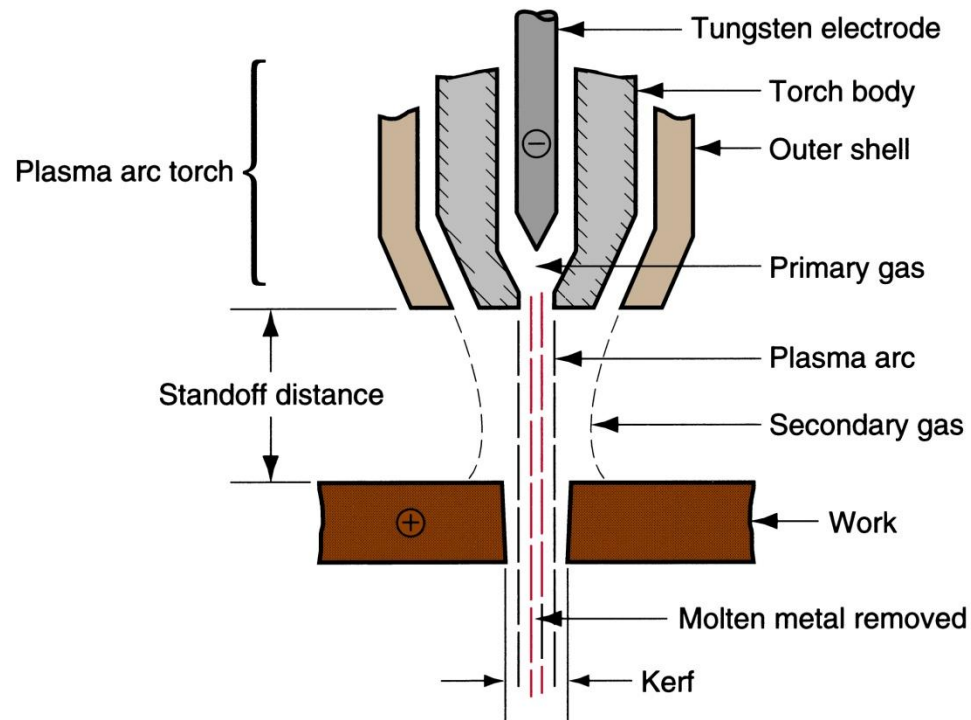
Fig. 9.2 Details of air plasma torch construction [*Benedict, 1987*;
Courtesy: W.A. Whitney Corp. Rockford, III.]





Plasma Arc Cutting (PAC)

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



Overall Machining Tolerances and Surface Roughness

