**Introduction**

Machining processes produce finished products with a high degree of accuracy and surface quality. Conventional machining utilizes cutting tools that must be harder than workpiece material. The difficulty to cut materials encouraged efforts that led to the introduction of the unconventional machining processes that are well-established in modern manufacturing industries.

**Definition:** *Unconventional Machining* - A type of machining which does not use a mechanical means such as physical contact with a grinder, cutting blade, broach, etc. to accomplish the removal of material from the workpiece.

**Importance of unconventional processes**

- 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 readily be accomplished by conventional machining.
- Need to avoid surface damage that often accompanies conventional machining.

**Introduction**

A group of processes that remove excess material by various techniques involving mechanical, thermal, electrical, or chemical energy (or combinations of these energies).

- They do not use a sharp cutting tool in the conventional sense.
- Developed since World War II in response to new and unusual machining requirements that could not be satisfied by conventional methods.
Classification of Unconventional processes

- **Thermal** - thermal energy usually applied to small portion of work surface, causing that portion to be fused and/or vaporized

- **Mechanical** - typical form of mechanical action is erosion of work material by a high velocity stream of abrasives or fluid (or both)

- **Electrical** - electrochemical energy to remove material (reverse of electroplating)

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

Laser beam machining
Plasma arc machining
Electric discharge machining/wire cutting

**Laser Beam Machining (LBM)**

Laser Beam Machining (LBM) uses the light energy from a laser to remove material by vaporization and ablation.

**Laser**

Laser = "Light Amplification by Stimulated Emission of Radiation"

Laser converts electrical energy into a highly coherent light beam with the following properties:
- Monochromatic (single wavelength)
- Highly collimated (light rays are almost perfectly parallel)

These properties allow laser light to be focused, using optical lenses, onto a very small spot with resulting high power densities.

**Laser Application**
- Cutting
- Welding
- Heat Treatment/Cladding
- Marking

**Work materials**: metals with high hardness and strength, soft metals, ceramics, glass and glass epoxy, plastics, rubber, cloth, and wood
Laser samples

Plasma Arc Cutting

Operation of PAC

- Plasma = a superheated, electrically ionized gas
- PAC temperatures: 10,000°C to 14,000°C (18,000°F to 25,000°F)
- Plasma arc is generated between electrode in torch and anode workpiece
- The plasma flows through water-cooled nozzle that constricts and directs stream to desired location

Applications of PAC

- Most applications of PAC involve cutting of flat metal sheets and plates
- Can be operated by hand-held torch or automated by CNC
- Can cut any electrically conductive metal
- Most frequently cut metals: carbon steel, stainless steel, aluminum

PAC sample

Uses plasma stream operating at very high temperatures to cut metal by melting
**ED 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:

- *Electric discharge machining*
- *Wire electric discharge machining*

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**Electric Discharge Machining (EDM)**

![Diagram of EDM process](image)

(a) overall setup, and (b) close-up view of gap, showing discharge and metal removal.

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**EDM operation**

- One of the most widely used nontraditional processes
- Shape of finished work surface produced by a shape of electrode tool
- Sparks occur across a small gap between tool and work
- Requires dielectric fluid, which creates a path for each discharge as fluid becomes ionized in the gap

**Work Materials in EDM**

- Work materials must be electrically conducting
- Hardness and strength of work material are not factors in EDM
- Material removal rate depends on melting point of work material
Electric discharge wire cutting

Operation of wire EDM
- Work is fed slowly past wire along desired cutting path, like a band-saw operation
- CNC used for motion control
- While cutting, wire is continuously advanced between supply spool and take-up spool to maintain a constant diameter
- Dielectric required, using nozzles directed at tool-work interface or submerging work part

Wire EDM Applications
Ideal for stamping die components
Since kerf is so narrow, it is often possible to fabricate punch and die in a single cut

Mechanical Energy Processes
- Typical form of mechanical action is erosion of work material by a high velocity stream of abrasives or fluid (or both)
  - Water jet cutting
  - Abrasive water jet cutting

Water Jet Cutting (WJC)
- 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
- WJC Advantages
  - No crushing or burning of work surface
  - Minimum material loss
  - No environmental pollution
  - 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 after it exits nozzle

Electro Chemical Machining Processes

- **ECM**
  - Material removal by anodic dissolution, using electrode (tool) in close proximity to work but separated by a rapidly flowing electrolyte
  - Work material must be a conductor

- **Process:**
  - Electrochemical machining (ECM)

ECM Operation

- Material is depleted from anode workpiece (positive pole) and transported to a cathode tool (negative pole) in an electrolyte bath
- Electrolyte flows rapidly between two poles to carry off depleted material, so it does not plate onto tool
- Electrode materials: Cu, brass, or stainless steel
- Tool has inverse shape of part
- Tool size and shape must allow for the gap

**ECM Applications**

- Die sinking -irregular shapes and contours for forging dies, plastic molds, and other tools.
- Multiple hole drilling -many holes can be drilled simultaneously with ECM.
- Holes that are not round, since rotating drill is not used in ECM
- De burring

ECM Samples
COMPARISON

<table>
<thead>
<tr>
<th>Process</th>
<th>Characteristics</th>
<th>Process parameters and typical material removal rate or cutting speed</th>
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<tbody>
<tr>
<td>Electrochemical machining (ECM)</td>
<td>Complex shapes with deep cavities; highest rate of material removal among nontraditional processes; expensive tooling and equipment; high power.</td>
<td>V: 5–25 dc; A: 1.1–8 A/mm²; 2.5–12 mm/min, depending on current density.</td>
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<tr>
<td>Electrical-discharge machining (EDM)</td>
<td>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.</td>
<td>V: 50–300; A: 0.1–1000; Typically 100 mm³/min.</td>
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<tr>
<td>Wire EDM</td>
<td>Contour cutting of flat or curved surfaces; expensive equipment.</td>
<td>Varies with material and thickness.</td>
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<tr>
<td>Laser-beam machining (LBM)</td>
<td>Cutting and hole making on thin materials; heat-affected zone; does not require a vacuum; expensive.</td>
<td>0.5–7.5 m/min.</td>
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<tr>
<td>Electron-beam machining (EBM)</td>
<td>Cutting and hole making on thin materials; very small holes and slots; heat affected zone; requires a vacuum; expensive equipment.</td>
<td>1–2 mm³/min.</td>
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<td>Water-jet machining (WJM)</td>
<td>Cutting all types of nonmetallic materials to 25 mm and greater in thickness; suitable for contour cutting of flexible materials; no thermal damage; noisy.</td>
<td>Varies considerably with material.</td>
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<tr>
<td>Abrasive water-jet machining (AWJM)</td>
<td>Single or multilayer cutting of metallic and nonmetallic materials.</td>
<td>Up to 7.5 m/min.</td>
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<tr>
<td>Abrasive-jet machining (AJM)</td>
<td>Cutting, slotting, de-burring, de-flashing, etching, and cleaning of metallic and nonmetallic materials; manually controlled; tends to round off sharp edges; hazardous.</td>
<td>Varies considerably with material.</td>
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