Non-traditional Machining Processes

(Chap 9 in Textbook)
Outline

- Grinding
- Ultrasonic machining
- Chemical machining
- Electro-chemical machining
- Electrical-discharge machining
- High-energy-beam machining
- Water-jet and Abrasive jet machining
When do we need non-traditional processes

• Very high hardness and the strength of the material.
• The workpiece is difficult to clamp or flexible.
• Complexity of the workpiece shape.
• Strict surface finish requirement.
• Tight dimensional tolerances.
• Undesirable rise in temperature could damage the workpiece.
Grinding
Abrasives for Grinding

- Common abrasives
  - Aluminum oxide
  - Silicon carbide
- Super abrasives
  - Cubic boron nitride
  - Diamond

Characteristics of abrasives
- Friability - self-sharpening
- Shape – sharp edge
- Size – grit number

<table>
<thead>
<tr>
<th>Material</th>
<th>Knoop Hardness Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common glass</td>
<td>350-500</td>
</tr>
<tr>
<td>Flint, quartz</td>
<td>800-1100</td>
</tr>
<tr>
<td>Zirconium oxide</td>
<td>1000</td>
</tr>
<tr>
<td>Hardened steels</td>
<td>700-1300</td>
</tr>
<tr>
<td>Tungsten carbide</td>
<td>1800-2400</td>
</tr>
<tr>
<td>Aluminum oxide</td>
<td>2000-3000</td>
</tr>
<tr>
<td>Titanium nitride</td>
<td>2000</td>
</tr>
<tr>
<td>Titanium carbide</td>
<td>1800-3200</td>
</tr>
<tr>
<td>Silicon carbide</td>
<td>2100-3000</td>
</tr>
<tr>
<td>Boron carbide</td>
<td>2800</td>
</tr>
<tr>
<td>Cubic boron nitride</td>
<td>4000-5000</td>
</tr>
<tr>
<td>Diamond</td>
<td>7000-8000</td>
</tr>
</tbody>
</table>

TABLE 9.1  Knoop hardness range for various materials and abrasives.
Grinding Wheel

FIGURE 9.1 Schematic illustration of a physical model of a grinding wheel, showing its structure and grain wear and fracture patterns.
FIGURE 9.7  (a) Grinding chip being produced by a single abrasive grain. Note the large negative rake angle of the grain. Source: After M.E. Merchant. (b) Schematic illustration of chip formation by an abrasive grain. Note the negative rake angle, the small shear angle, and the wear flat on the grain.
Grinding Wheel Wear

- Attritious wear
- Grain fracture
  - Selection guide for grinding wheel
    - Aluminium oxide – steel, ferrous alloys and alloy steels
    - Silicon carbide – non ferrous, hard and brittle materials
    - Diamond – ceramics, hardended steels
    - Cubic boron nitride – steels and cast irons of 50 HRC or above, high temperature alloys
- Bond fracture
Grinding Fluid

- Function
  - Prevent excessive temperature rise in workpiece
  - Improve part’s surface finish and dimensional accuracy
  - Improve grinding efficiency
Chemical-Mechanical Planarization

FIGURE 9.22 Schematic illustration of the chemical-mechanical polishing process. This process is widely used in the manufacture of silicon wafers and integrated circuits, where it is known as chemical-mechanical planarization. Additional carriers and more disks per carrier also are possible.
Ultrasonic Machining

FIGURE 9.24  (a) Schematic illustration of the ultrasonic-machining process; material is removed through microchipping and erosion with abrasive particles.

- Typical vibration amplitude of sonotrode – 0.05-0.125 mm, freq ~ 20 kHz

- Best for hard and brittle materials – ceramics, carbides, glass, precious stones, hardened steels
FIGURE 9.26 (a) Schematic illustration of the chemical machining process. Note that no forces are involved in this process. (b) Stages in producing a profiled cavity by chemical machining.
FIGURE 9.25 (a) Missile skin-panel section contoured by chemical milling to improve the stiffness-to-weight ratio of the part. (b) Weight reduction of space launch vehicles by chemical milling of aluminum-alloy plates. These panels are chemically milled after the plates have first been formed into shape, such as by roll forming or stretch forming. *Source: ASM International.*
Electrochemical Machining

- Works on the principle of electrolysis
- 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

FIGURE 9.29 Schematic illustration of the electrochemical-machining process.
Electrical Discharge Machining

FIGURE 9.32 Schematic illustration of the electrical-discharge-machining process.
Wire EDM

FIGURE 9.35 Schematic illustration of the wire EDM process. As much as 50 hours of machining can be performed with one reel of wire, which is then recycled.
Lasers are high intensity focused light sources

• Limited in depth of cut (focus of light)

• Would limit workpiece to less than 1 inch (< ½” typically)
Electron-Beam Machining

FIGURE 9.37  Schematic illustration of the electron-beam machining process. Unlike LBM, this process requires a vacuum, and hence workpiece size is limited by the chamber size.

- High velocity electrons strike the work surface to generate heat
- Used for accurate cutting
- Need vacuum chamber
- Interaction of electron with work piece generates X-rays
Water-Jet Machining

FIGURE 9.38  (a) Schematic illustration of water-jet machining. (b) A computer-controlled water-jet cutting machine. (c) Examples of various nonmetallic parts machined by the water-jet cutting process. Source: Courtesy of OMAX Corporation.
Abrasive-Jet Machining

- 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
Summary

• Grinding
• Ultrasonic machining
• Chemical machining
• Electro-chemical machining
• Electrical-discharge machining
• High-energy-beam machining
• Water-jet and Abrasive jet machining

Principles, applications, process parameters