Lecture 13

Chapter 22
Cutting-Tool Materials
and
Cutting Fluids

Cutting Tools

• Cutting Tools are subjected to:
  – High temperatures
  – High contact stresses
  – Rubbing
    • Tool-chip interface
    • Machined surface

• Important properties
  – Hot hardness
  – Toughness and impact strength
  – Thermal shock resistance
  – Wear resistance
  – Chemical stability and inertness
Cutting Tool Hardness

- Hot hardness
  - Hardness / Strength
  - Wear resistance

General Properties of Cutting Tool Materials

Table 21.1

<table>
<thead>
<tr>
<th>Property</th>
<th>High-speed steels</th>
<th>Cast alloys</th>
<th>Carbides</th>
<th>Cubic boron nitride</th>
<th>Single-crystal diamond</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness</td>
<td>83–90 HRA</td>
<td>90–96 HRA</td>
<td>91–95 HRA</td>
<td>1810–3200 HK</td>
<td>3000–5000 HK</td>
</tr>
<tr>
<td>Compressive strength, MPa</td>
<td>4100–4500</td>
<td>1500–2500</td>
<td>4100–5550</td>
<td>3100–3750</td>
<td>2770–4500</td>
</tr>
<tr>
<td>Impact strength, J</td>
<td>1.35–4</td>
<td>0.54–1.25</td>
<td>0.56–1.35</td>
<td>0.79–1.24</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>Modulus of elasticity, GPa</td>
<td>200</td>
<td>350–490</td>
<td>350–490</td>
<td>350–490</td>
<td>800</td>
</tr>
<tr>
<td>Density, kg/m³</td>
<td>8000</td>
<td>8000–8700</td>
<td>10,000–13,000</td>
<td>5500–8500</td>
<td>4000–4500</td>
</tr>
<tr>
<td>Volume fraction, %</td>
<td>7–15</td>
<td>7.5–9</td>
<td>10–20</td>
<td>70–90</td>
<td>70–90</td>
</tr>
<tr>
<td>Melting or decomposition, °C</td>
<td>1300</td>
<td>1300</td>
<td>1400</td>
<td>1400</td>
<td>2000</td>
</tr>
<tr>
<td>Thermal conductivity, W/m K</td>
<td>2370</td>
<td>2370</td>
<td>2500</td>
<td>2500</td>
<td>5000</td>
</tr>
<tr>
<td>Coefficient of thermal expansion, 10°C⁻¹</td>
<td>12</td>
<td>4–6.5</td>
<td>7.5–9</td>
<td>6–8.5</td>
<td>4.8</td>
</tr>
</tbody>
</table>

*The values for polycrystalline diamond are generally lower, except impact strength, which is higher.
### TABLE 21.2

**General Characteristics of Cutting Tool Materials**

<table>
<thead>
<tr>
<th>Tool Materials</th>
<th>Low-hardness alloys</th>
<th>High-speed steels</th>
<th>Cast-cobalt alloys</th>
<th>Uncoated carbides</th>
<th>Coated carbides</th>
<th>Ceramics</th>
<th>Polycrystalline cubic boron nitride (cBN)</th>
<th>Diamond</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness</td>
<td>Increasing</td>
<td>Increasing</td>
<td>Increasing</td>
<td>Increasing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toughness</td>
<td>Increasing</td>
<td>Increasing</td>
<td>Increasing</td>
<td>Increasing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact strength</td>
<td>Increasing</td>
<td>Increasing</td>
<td>Increasing</td>
<td>Increasing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wear resistance</td>
<td>Increasing</td>
<td>Increasing</td>
<td>Increasing</td>
<td>Increasing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cutting speed</td>
<td>Increasing</td>
<td>Increasing</td>
<td>Increasing</td>
<td>Increasing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal-shock resistance</td>
<td>Increasing</td>
<td>Increasing</td>
<td>Increasing</td>
<td>Increasing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tool material cost</td>
<td>Light to heavy</td>
<td>Light to heavy</td>
<td>Light to heavy</td>
<td>Light to heavy</td>
<td>Light to heavy</td>
<td>Light to heavy</td>
<td>Light for single crystal diamond</td>
<td>Light for single crystal diamond</td>
</tr>
<tr>
<td>Depth of cut</td>
<td>Light to heavy</td>
<td>Light to heavy</td>
<td>Light to heavy</td>
<td>Light to heavy</td>
<td>Light to heavy</td>
<td>Light to heavy</td>
<td>Light for single crystal diamond</td>
<td>Light for single crystal diamond</td>
</tr>
<tr>
<td>Finish obtainable</td>
<td>Rough to Wrought</td>
<td>Rough to Wrought, cast, HIP sintering</td>
<td>Rough to Wrought, cast, HIP sintering</td>
<td>Good to Very good</td>
<td>Very good</td>
<td>Very good</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td>Method of processing</td>
<td>Machining and grinding</td>
<td>Machining and grinding</td>
<td>Machining and grinding</td>
<td>Grinding and polishing</td>
<td>Grinding and polishing</td>
<td>Grinding and polishing</td>
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<td>Grinding and polishing</td>
</tr>
<tr>
<td>Fabrication</td>
<td>Machining and grinding</td>
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<td>Machining and grinding</td>
<td>Grinding and polishing</td>
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</tr>
</tbody>
</table>

**Notes:**
1. Hot- isostatic pressing.
2. Chemical-vapor deposition, physical-vapor deposition.

- HSS are tough, but have a limited hot hardness
- Ceramics are resistant to T, but are brittle
High Speed Steels (HSS)

- Properties
  - Highly Alloyed
  - Good wear resistance
  - Relatively inexpensive
  - Excellent (relative) toughness

- Suitable for
  - High, positive rake-angle tools
  - Interrupted cuts
  - Machine tools with low stiffness / vibration
  - Complex single-piece tools

Cast Cobalt Alloys

- Properties
  - High hardness
  - Good wear resistance
  - Good hot hardness
  - Not as good as HSS for interrupted cuts
Carbides

- Properties
  - High hardness over wide range of T's
  - High E
  - High thermal conductivity
  - Low thermal expansion

- Tungsten Carbide (WC)
  - WC in Co matrix
  - An increase in Co
    - Decreases strength
    - Decreases hardness
    - Decreases wear resistance
    - Increases toughness

- Titanium Carbide (TiC)
  - TiC in a nickel-molybenum matrix
  - Higher wear resistance than WC
  - Not as tough as WC

Inserts

- HSS are shaped in one piece
- Other materials are typically supplied as inserts
  - Multiple cutting points
  - Quick change of cutting point
Relative Strength of Cutting Tool Geometries

- The smaller the included angle, the lower the strength of the edge

Machine Tool Characteristics

- Stiffness of the machine tool is of major importance
  - Damage to tool’s cutting edge
    - Light feeds
      - Concentrates forces closer to edge of tool
      - Concentrates temperature closer to edge of tool
    - Low speeds
      - Cold welding of chip to tool
    - Chatter