Lecture 14

Chapter 22
Cutting-Tool Materials
and
Cutting Fluids
(continued)

Tool Coatings

• Why are coatings employed?
  – Lower friction
  – Higher adhesion
  – Higher resistance to wear and cracking
  – Diffusion barrier
  – Increase hot hardness and impact resistance

• Tool life is, on average, 10 times longer for coated tools
• Machining time has been reduced by more than a factor of 100 since 1900
Tool Coatings

• Desirable characteristics of tool coatings
  – High hardness
  – Chemical stability
  – Low thermal conductivity
  – Compatibility and good bonding
  – Little to no porosity

• Typical coatings are:
  – TiN
  – TiC
  – TiCN
  – TiCN
  – Al₂O₃
  – Applied by
    • CVD Processes (Chemical Vapor Deposition)
    • PVD Processes (Physical-Vapor Deposition)
  – 2 – 15 μm thick
Tool Coatings

• TiN
  – Low friction coefficients
  – High hardness
  – Resistance to high temperature
  – Good adhesion
  – Flank wear lessened
  – Avoid low speeds – chip adhesion

• Diamond
  – Polycrystalline diamond deposited on SiN inserts
  – Uses
    • Nonferrous metals
    • Abrasives – Al alloys with Si
    • Graphite

• TiC
  – Deposited on WC inserts
  – High flank-wear resistance on abrasive materials

• Ceramic
  – Chemical inertness
  – Low thermal conductivities – transfer more heat to chip
  – Resistance to high temperature
  – Resistance to flank and crater wear
  – Weak bonding to substrate
Multiphase Coatings
- First layer – good bonding characteristics
- Outer layer – wear resistant / low thermal conductivity
- Examples
  - High-speed, continuous cutting TiC / Al₂O₃
  - Heavy-duty, continuous cutting: TiC / Al₂O₃ / TiN
  - Light, interrupted cutting: TiC / TiC + TiN/TiN
- Thinner layers are harder than thicker layers (?)
Tool Coatings

• Primary coating functions
  – TiN: low friction
  – Al₂O₃: high thermal stability
  – TiCN: good flank and crater wear – interrupted cuts

• Function of carbide substrate
  – Thin-carbide substrate: high fracture toughness
  – Thick-carbide substrate: hard and resistant to plastic deformation at high T’s

Multiphase Coating
Ranges of Mechanical Properties for Tooling Materials

- **Diamond, cubic boron nitride**
  - Very high wear resistance
  - Cutting edge strength
  - Chemical inertia to Fe and Ni
  - Avoid vibrations – stiff tool
  - Dry cutting only
  - Avoid interrupted cutting – thermal cycling
Tooling Costs

• Tooling costs
  – 2-4% of manufacturing costs
  – Tool life on average 30 – 60 minutes
  – Why not use shorter life tools that are cheaper?

<table>
<thead>
<tr>
<th>Tool</th>
<th>Size (in.)</th>
<th>Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-speed steel tool bits</td>
<td>1/4 sq x 2 1/2 long</td>
<td>1–2</td>
</tr>
<tr>
<td></td>
<td>1/2 sq x 4</td>
<td>3–7</td>
</tr>
<tr>
<td>Carbide-tipped (brazed) tools for turning</td>
<td>1/4 sq</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>3/4 sq</td>
<td>4</td>
</tr>
<tr>
<td>Carbide inserts, square 3/16&quot; thick</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plain</td>
<td>1/2 inscribed circle</td>
<td>5–9</td>
</tr>
<tr>
<td>Coated</td>
<td></td>
<td>6–10</td>
</tr>
<tr>
<td>Ceramic inserts, square</td>
<td>1/2 inscribed circle</td>
<td>8–12</td>
</tr>
<tr>
<td>Cubic boron nitride inserts, square</td>
<td>1/2 inscribed circle</td>
<td>60–90</td>
</tr>
<tr>
<td>Diamond-coated inserts</td>
<td>1/2 inscribed circle</td>
<td>50–60</td>
</tr>
<tr>
<td>Diamond-tipped inserts (polycrystalline)</td>
<td>1/2 inscribed circle</td>
<td>90–100</td>
</tr>
</tbody>
</table>

Cutting Fluids

• Primary purposes
  – Reduce friction and wear
  – Cool the cutting zone
  – Reduce forces and energy consumption
  – Flush away the chips
  – Protect machined surface from environmental corrosion

• Drawbacks
  – Chips may curl more – heat concentration at tip
  – Thermal cycling - milling
Cutting Fluids

• Severity of machining processes – the more severe the more necessary a cutting fluid is
  – Sawing
  – Turning
  – Milling
  – Drilling
  – Gear cutting
  – Thread cutting
  – Tapping
  – Internal broaching

Types of Cutting Fluids

• Types
  – Oils
    • Low speed operations
    • T rise is not significant
  – Emulsions – mixture of oil and water
    • T rise is significant
  – Semisynthetics
    • Little mineral oil diluted in water
    • Additives make oil particles smaller
  – Synthetics
    • Chemicals with additives diluted in water
Cutting Fluid Application

- Flooding
  - Single point
    • 10 L/min
  - Multiple point
    • 225 L/min
- Mist
  - For inaccessible areas
- High pressure
  - Directed at flank
  - Through the cutting tool

Near-Dry Machining

- NDM
  - Alleviates environmental impact of machining fluids
    • US generates millions of gallons of waste a year
  - Reducing the cost of the machining operation
    • 7-17% of manufacturing cost
  - Further improves surface quality
    • Use advanced cutting tools