Machining Techniques for Difficult Titanium Alloys

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Machining Techniques for Difficult Titanium Alloys

• Types of Ti Alloys
  – Alpha
  – Alpha/Beta
  – Beta
  – Gamma Ti

Pure Ti  
Ti 6-4  
Ti 17, Beta-C, etc.  
Ti-Al, Ti₃Al, etc.
Advantages of Difficult Alloys

- Lightweight
- Strong at elevated temperatures
- Gamma Ti alloys are burn resistant
- Attractive to industry
  - Aerospace
  - Auto racing
## Machinability Ratings

<table>
<thead>
<tr>
<th>Material</th>
<th>Machinability Rating</th>
<th>Number of Inserts Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Al alloy</td>
<td>140</td>
<td>0.6</td>
</tr>
<tr>
<td>B1112</td>
<td>100</td>
<td>1</td>
</tr>
<tr>
<td>Ductile iron, 4140</td>
<td>50</td>
<td>2</td>
</tr>
<tr>
<td>Ti 6Al 4V</td>
<td>35</td>
<td>3</td>
</tr>
<tr>
<td>IN 718</td>
<td>15</td>
<td>6.5</td>
</tr>
<tr>
<td>Ti Al</td>
<td>5</td>
<td>20</td>
</tr>
</tbody>
</table>
Machinability

• Beta and Gamma alloys are difficult to machine
  – No matter what technique is used, tool life is poor
  – Try to minimize amount of stock to be removed
Machining Difficulties

• Good high temperature strength
  – High stress on cutting
  – Tends to “crush” the cutting edge
• Poor thermal conductivity
  – Heat concentrated at cutting edge
  – Tends to promote deformation and cratering
• Ti chemically reactive
• Low ductility
  – Surface and sub-surface cracking

Photo courtesy of Aspinwall, et. al.
University of Birmingham
Machining Techniques

• Traditional techniques
  – Micrograin carbide
  – High speed, trochoidal, and optimized roughing milling
  – High lead angles in turning
  – High pressure coolant

• Non-traditional techniques
  – Diamond tools
  – Laser assisted machining
Machining Techniques

• Micrograin carbide
  – Excellent cutting edge integrity
  – Improved workpiece surface finish
  – Optimized combination of hardness and toughness (Poisson effect)
High Pressure Coolant

• High pressure coolant may result in 10 fold improvement in tool life compared to conventional coolant
• Flow rate may be more important than pressure
• Running at too high pressure generates chips that interrupt coolant flow
High Pressure Coolant

• A range of high performance tools designed to deliver coolant directly at the insert cutting zone.

• Capable of delivering coolant pressures ranging from 15 – 4000 psi (1 to 275 bar)
High Pressure Coolant

Titanium 6AL4V
Low 'Thermal Conductivity &
Low Modulus of Elasticity.

Small Concentrated
Heat Zone

Cutting data 130 – 200 sfpm
Tool life is typically 20 minutes
Failure mode – typically flank wear
Feature - Long uncontrollable chips

Thin, High Velocity
Chip

Conventional Coolant

Don Graham  Seco Tools

October 6-9, 2013 • Caesars Palace, Las Vegas, Nevada, USA
High Pressure Coolant

Pressurised jet of coolant, directed at the cutting zone

Reduces temperature in cutting zone
Allowing higher cutting speed and longer tool life

Coolant pressure deflects chips to break into smaller more manageable pieces

Pressurised jet of coolant, directed at the cutting zone
High Pressure Coolant

- Improved chip control
- Improved tool-life
- Increased cutting data
- Improved surface finish
Diamond Tools for Titanium

- PCD30M Triple hone: 45 minutes
- 883 WC: 10 minutes
- PCD30M Honed: 1 minute
- PCD30M sharp: 0.3 minutes
Diamond Tools for Titanium

\[ V_c = 200 \text{m/min, } f = 0.15 \text{ mm/rev, } ap = 0.25 \text{mm, } CP = 150 \text{bar, RCMW100300 E50} \]
High Speed Machining

• Milling Techniques

  • Small cutting depth
  • Small radial cutting depth
  • Maintain average chip thickness
  • High cutting speed
  • Sharp cutting edges in hard grades
Average Chip Thickness

90deg

f_z : 100%

h : 100%

45deg

h : 70%

f_z : 100%
Average Chip Thickness

\[ h = f_z \times \sin (\chi) \]
High Feed Milling
Trochoidal/Hard Milling
Trochoidal and High Feed Milling
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