Improving Performance in Milling of Titanium Structures

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Agenda

• Customer Driven Productivity Improvement
• Challenges in machining Titanium
• Thermal Management
• Taking Costs Out
Customer Driven Productivity Improvement

2X increase Ti in Airframe

Drive to Reduce Ti Machining Cost by 50%

Customer Requirements

- Double productivity
- Increase tool life
- Increase reliability
- Milling compatible

One large aerospace customer points out that MRR for Aluminum went down over the years. Not so for Titanium.
Challenges in Machining Titanium

90% of work from metal cutting is converted into heat

Titanium Characteristics

- Good high temperature strength increases the work needed to cut Titanium.
- High work hardening and strain rate sensitivity exacerbate thermal issues in cutting Ti alloys.
- Titanium reacts with all materials at high temperatures to chemically wear tools.
- Poor thermal conductivity of Ti causes heat to partition to the tool instead of the chip.
Effect of Cutting Speed on Temperature

Current Ti cutting conditions

Double Cutting Speed

- 50 m/min at 0.15 mm chip
- 100 m/min at 0.15 mm chip

FEM predicts a 250°C increase in cutting temperature to double speed
Coolant Application Effects

- **Thermal**
  - 90% of work converted to heat
  - Low conductivity workpieces retain heat
  - Coolant systems flush chip backside

- **Lubrication**
  - Tool/chip friction generates heat
  - Tool/chip friction increase shear stress
  - Good lubrication reduces both

- **Chip Evacuation**
  - External coolant pushes chip into cut
  - Recutting chips accelerates failure
  - Internal coolant assists evacuation

*Coolant composition, delivery pressure, volume flow rate and impingement location affects the metal cutting performance.*
KSSM45 Milling Tool Development

Cutting Conditions

Workpiece: Ti6Al4v
Hardness: 42 – 46 HRC
Length of Pass: 254mm (10 in)
Cutting Fluid: Water based Synth.
Coolant Pressure: 300 psi.

Cutting Parameters

Cutting Speed: 58 m/min (187 SFM)
Chip load (fz): 0.25mm/tooth (0.010 ipt)
Axial Depth of Cut = 2 mm (0.08 inch)
Radial Depth of Cut = 81 mm (3.2 inch)

KSSM45 Beyond Blast™ provided over 2 times better tool life than standard through spindle coolant delivery.
Daisy Milling Tool Development

Cutting Conditions

- Workpiece: Ti6Al4v
- Hardness: 42 – 46 HRC
- Length of Pass: 254mm (10 in)
- Cutting Fluid: Water based Synth.
- Coolant Pressure: 1000 psi.

Cutting Parameters

- Cutting Speed: 46 m/min (150 SFM) & 58 m/min (187 SFM)
- Chip load (fz): 0.25mm/tooth (0.010 ipt)
- Axial Depth of Cut = 3.8 mm (0.15 inch)
- Radial Depth of Cut = 51 mm (2.0 inch)

T114526 & T117470 Daisy Round Inserts

Beyond Blast vs. Standard Through Spindle Coolant

- DAISY Beyond Blast™ provided over 2.5 times better tool life than standard through spindle coolant delivery @ 150 SFM.
Integrated Thermal Management

Coolant application has a large effect on tool performance
It’s Not Just About the Tools: It Is About Partnerships, Digitization and Integration

A Complex Iterative Process

Design Part with CAD → Select Machine → Select Tools → Write & Optimize Program → Produce Part → Inspection

That Can be Optimized

Baseline vs. Optimized

The Opportunity

Forging/Casting | Machine Tool | Cutting Tools | Machining | Other

It Is About Partnerships, Digitization and Integration
Total Solution Set
Rough Milling
 Finish Milling
 Hole Making

Digitization and Integration of Best Practices
## The Bottom Line: Productivity!

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Current Process</th>
<th>New Process</th>
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<tr>
<td>Batch Size</td>
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<tr>
<td>Number of Machines &amp; Spindles</td>
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<td>Maximum Production Rate</td>
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<td>Floor Space / Machine Footprint</td>
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The Bottom Line: Productivity!
Overcoming Chatter

“Tunable” Boring Bar
Boeing 777 Landing Gear - 300M Steel

“Tunable” HARVI Cutters™
MH-53 Rotor - Ti 6Al4V

Plunge Mills

Wavy edge tools

Differential Pitch
Conclusion – Integrated Performance

- Machining of Ti alloys present many unique challenges due to the high strength, chemical reactivity and poor thermal conductivity.

- The optimum machining productivity combines metalcutting application knowledge, materials science expertise and advanced manufacturing technology.

- Thermal management has a large role in overall performance

Beyond Imagination!