Titanium & Metalworking Fluids

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September 16, 2009
Metal Removal Process

- Part
- Machine Tool
- Cutting Tool / Grinding Wheel
- Metal Removal Fluid
Metalworking Fluid Functions

• COOLING - REMOVE HEAT

• LUBRICATION - PREVENT HEAT

• MOVE CHIPS
Metalworking Fluid Benefits

• Reduce Cutting Temperatures
• Reduce Cutting Forces
• Extend Tool Life
• Reduce Workpiece Temperature
• Improve Dimensional Stability
• Improve Workpiece Finish

September 16, 2009
Fact about titanium

- Titanium is a poor conductor of heat.
- Heat generated by the cutting action does not dissipate quickly.
- Most of the heat is concentrated on the cutting edge and the tool face.

Therefore: a metalworking fluid is important to reduce the heat
Fact about titanium

• Titanium has a strong alloying tendency or chemical reactivity with materials in the cutting tools at tool operating temperatures.
• This can cause galling, welding and smearing along with rapid destruction of the cutting tool.

Therefore: a metalworking fluid is important to reduce the heat
Fact about titanium

- Titanium has a low modulus of elasticity, such that the work-piece tends to move away from the cutting tool unless heavy cuts are maintained.
- Slender parts tend to deflect under tool pressure and this can cause chatter, tool rubbing and tolerance problems.
- Rigidity of the entire machining system is important as is the use of sharp, properly shaped tools.

Therefore: a metalworking fluid is important to provide lubricity
Use generous amounts of cutting fluid

- Coolant carries away heat
- Coolant reduces cutting forces
- Coolant washes away chips

Water-based fluids are the best choices to provide heat dissipation and good cleanliness for machining titanium.
Fig. 1—Tool life when machining Ti-6Al-4V alloy with uncoated carbide inserts under various machining conditions.

To cite this Article Ezugwu, E. O., Bonney, J., Da Silva, R. B., Machado, A. R. and Ugwoha, E.(2009)'High Productivity Rough Turning of Ti-6Al-4V Alloy, with Flood and High-Pressure Cooling', Tribology Transactions, 52:3, 395 — 400
Fig. 2—Nose wear rate curves when machining Ti-6Al-4V alloy with uncoated carbide inserts at various cutting conditions.

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Metalworking Fluid “Other” Functions

- Rust Control
- Microbial Control
- Machine Cleanliness
- Foam Control especially under high pressure applications
- Acceptable Workplace Environment
- Acceptable Part Visibility (where needed)
## Types of Metalworking Fluids

<table>
<thead>
<tr>
<th>Type</th>
<th>% Mineral Oil in Concentrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>STRAIGHT OIL</td>
<td>Approx. 100</td>
</tr>
<tr>
<td>SOLUBLE OIL</td>
<td>40 - 90</td>
</tr>
<tr>
<td>- Commodity</td>
<td></td>
</tr>
<tr>
<td>- Premium</td>
<td></td>
</tr>
<tr>
<td>SEMI-SYNTHETIC</td>
<td>5 - 30</td>
</tr>
<tr>
<td>SYNTHETIC</td>
<td>0</td>
</tr>
<tr>
<td>- Simple</td>
<td></td>
</tr>
<tr>
<td>- Complex</td>
<td></td>
</tr>
<tr>
<td>- Emulsifiable</td>
<td></td>
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</tbody>
</table>
Chemical considerations with using coolant on titanium

• Chloride ions have under certain circumstances caused stress corrosion cracking in laboratory testing of titanium alloys.
• Sodium ions have also been implicated in stress cracking of titanium.
• Sources of chloride and sodium include the fluid formulation itself, as well as the water used to make the dilution.
# Boeing BAC 5008
## Application of Lubricants

### Table of Usage Areas

<table>
<thead>
<tr>
<th>SECTION</th>
<th>TEST TITLE</th>
<th>SEALANT / PAINT AREAS</th>
<th>HEAT-TREATED STEELS</th>
<th>DISSIMILAR METAL STACKUPS</th>
<th>AIRPLANE EXTERIOR ALUMINUM SURFACES</th>
<th>NONSEALANT/ NONPAINT AREAS</th>
<th>TITANIUM MACHINING GRINDING</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.1</td>
<td>Weight Change Corrosion (Steel and Aluminum)</td>
<td>X</td>
<td>X</td>
<td>X (Steel, Titanium, and Aluminum)</td>
<td>X (Steel and Aluminum)</td>
<td>X (Titanium)</td>
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<td>12.2</td>
<td>Stress Corrosion</td>
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<td>X</td>
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<td>12.3</td>
<td>Sandwich Corrosion (Clad/anodized aluminum)</td>
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<td>X</td>
<td></td>
<td>X</td>
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<td>12.4</td>
<td>Galvanic Corrosion (Steel/titanium/aluminum)</td>
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<td>X</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>12.5</td>
<td>Titanium Compatibility</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
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<tr>
<td>12.6</td>
<td>Sealant Compatibility</td>
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<td></td>
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<td></td>
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<tr>
<td>12.7</td>
<td>Paint Compatibility</td>
<td>X</td>
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<td></td>
<td>X</td>
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<td>12.8</td>
<td>Micro-Structural Effects</td>
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<td>X</td>
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</tr>
</tbody>
</table>
BAC 5008
12.1 Weight Change Corrosion

• Specimens include 6Al-4V Titanium plus steel and aluminum
• 4 specimens 1”x 2”x 0.05”
• Polish and weigh
• Immerse 2 in test fluid and 2 in DI water for 2 hours
• Drain
• Put in 140F / 50% humidity oven for 28 days
• Cool, rinse, dry and weigh
• Maximum allowable weight change for titanium 0.010 grams
BAC 5008
12.5 Titanium Compatibility

- Specimen 6Al-4V Titanium
- Specimens 0.75 "x 3"x 0.003"
- Clean and dry
- Immerse bent end of inner strip in test fluid and dry
- Insert bolt and load
- Dip bent end of each set in test fluid
- Expose for 7 days to 300F
- Cool, rinse, dry and examine
- Inspect both parts for evidence of attack/corrosion, pitting, cracking, or etching

September 16, 2009
Pratt & Whitney Fluid Tests

• Products must pass Stress Corrosion Test (ASTM F945) on titanium alloys **AMS 4911** (MIL-T-9046, Type III, Composition C; Alloy 6Al-4V) and **AMS 4916** (MIL-T-9046, Type II, Composition F; Alloy 8Al-1Mo-1V)

• Test specimens are covered with the test solution for one minute to wet, dried in an oven at 100F for one hour, then baked at 900F for 8 hours. Specimens are mounted for metallographic evaluation and examined at 500X for cracking.

• Requires reduced sodium and chlorine levels
Lockheed Martin

3.12 Coolants. Coolants shall be used during all machining operations on steel and titanium products and as necessary to prevent overheating when machining aluminum. Coolants shall not cause pitting, corrosion, or staining of machined parts. When machining titanium, deionized water or distilled water shall be used as the solvent unless written approval is obtained from LM Aero - Fort Worth F-22 M&PE. Non-halogenated cutting fluids shall be used when machining titanium unless otherwise approved by LM Aero - Fort Worth F-22 M&PE. Clean tap water is permissible when machining steel or aluminum.
Today’s Metalworking Fluid
Market Requirements

- Operator Safety
- Environmentally Safe
- Biostable
- Minimize Waste
- WWT Compatible
- Recyclable
- Cost Effective
- Consistent Quality
- Lubrication
- Corrosion Control
- Foaming / Mist
- Good Residue
- H₂O Quality Tolerant
- Easy to Control
- Filter Compatible
- Reject/Emulsify Oil

September 16, 2009
Introducing CIMTECH® 610 metalworking fluid

• An innovative new metalworking fluid featuring a blend of patented and synthetic lubricants
• Excellent heavy duty performance without oil or any EP (Extreme Pressure) lubricants: chlorine, sulfur, phosphorus.
• Typical operating pH of 7.8
• Good corrosion control on ferrous metals and non-staining to aluminum, titanium and other alloys.
• Low foam
• Good part visibility for machine operators
• Typical dilution, 5-10% with water
• Worldwide availability
V-Tool Test, Cutting Force
## Performance Data

<table>
<thead>
<tr>
<th>Test</th>
<th>V-tool Steel (Force)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy Duty Synthetic</td>
<td>418 lbs</td>
</tr>
<tr>
<td>Chlorinated Soluble Oil</td>
<td>474 lbs</td>
</tr>
<tr>
<td>Chlorine free Soluble Oil</td>
<td>442 lbs</td>
</tr>
<tr>
<td>Cimtech 610</td>
<td>356 lbs</td>
</tr>
</tbody>
</table>

*September 16, 2009*
Surface Grinder, G-Ratio
# Performance Data

<table>
<thead>
<tr>
<th>Test</th>
<th>V-tool Steel (Force)</th>
<th>G-ratio Steel (Rating)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy Duty Synthetic</td>
<td>418 lbs</td>
<td>5.5</td>
</tr>
<tr>
<td>Chlorinated Soluble Oil</td>
<td>474 lbs</td>
<td>4.0</td>
</tr>
<tr>
<td>Chlorine free Soluble Oil</td>
<td>442 lbs</td>
<td>5.5</td>
</tr>
<tr>
<td>Cimtech 610</td>
<td>356 lbs</td>
<td>7.5</td>
</tr>
</tbody>
</table>
MICROTAP

Tapping Torque Test Machine

Used for laboratory testing of products on steel, aluminum and titanium, using form taps
Microtap, Cutting Forces
# Machining Performance Data

<table>
<thead>
<tr>
<th>Test</th>
<th>V-tool Steel  (Force)</th>
<th>G-ratio Steel  (Rating)</th>
<th>MICROTAP  (form taps)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>6061 Al Uncoated (torque)</td>
</tr>
<tr>
<td>Heavy Duty Synthetic</td>
<td>418 lbs</td>
<td>5.5</td>
<td>184 Ncm</td>
</tr>
<tr>
<td>Chlorinated Soluble Oil</td>
<td>474 lbs</td>
<td>4.0</td>
<td>218 Ncm</td>
</tr>
<tr>
<td>Chlorine free Soluble Oil</td>
<td>442 lbs</td>
<td>5.5</td>
<td>219 Ncm</td>
</tr>
<tr>
<td>Cimtech 610</td>
<td>356 lbs</td>
<td>7.5</td>
<td>182 Ncm</td>
</tr>
</tbody>
</table>
Galling on taps
Applications with Cimtech 610

- **Fluid Concentration:** 10%
- **Part:** Aerospace
- **Material:** 6Al-4V Titanium
- **Operation:** Rough and finish end milling using solid carbide ball nosed 3/8” and 3/4” diameter end mills
- **System:** Individual sumps
- **Results:** The CIMTECH 610 had 5 times the tool life on roughing and 10 times tool life on finishing versus a chlorinated soluble oil.
Applications with Cimtech 610

- **Fluid Concentration**: 8%
- **Part**: Rear cockpit bulkhead for the F-22 Raptor
- **Material**: 6Al-4V Titanium
- **Operation**: Rough machining blocks
- **System**: 300 gallon tank on a horizontal machining center with 1000 psi through the tool fluid application via a high pressure fluid unit
- **Results**: Finishes were very good versus a chlorinated soluble oil, which caused chip removal issues because of “nesting”. The Cimtech 610 machined well, did not foam and resulted in chips that were easily managed.

*September 16, 2009*
Applications with Cimtech 610

- Milled 555-3 titanium for 7 hours in two tests with one tool on one spindle of a 5 spindle gantry mill
- 9-10% concentration
- Feed rate 3 inches (76.2mm) per minute
- 83 rpm
Conclusions

- Use of coolant is essential for effective machining of titanium.
- Insure that the coolant is compatible with the titanium and that it has passed the necessary qualification tests.
- Maintain coolant at the proper use dilution and keep it clean. Work with your supplier.
- High performance coolants are available to optimize titanium machining.