Best in Class Titanium Machining

ITA - September 2009
Company Profile

Kennametal Delivers Advanced Materials, Surface Technologies and Material Shaping Expertise to Customers Seeking Optimum Performance

- Delivering Solutions To Reduce Material Corrosion And Wear
- Improving Material Finishes
- Cutting And Forming Materials Into Complex Shapes
- Implementing New Super Hard Materials For Energy, Mining And Construction
- Developing One-of-a-Kind Specialty Applications In Multiple Industries

$2.7 Billion Revenues
80,000 + Active Customers
12,000 + Employees
1000 + Scientists / Engineers
1000 + Patents
60 + Global Countries

No Single Customer Accounts For More Than 3% Of Sales

Aerospace & Defense • Natural Resources • Infrastructure • Transportation • Durable Goods

Delivering Productivity to our Customers
- 47% Of Sales From Products Less Than 5 Years Old — Up From 17% In The Late 90’s

- Averaging 40-50 U.S. Patents Per Year

- Highly Trained And Experienced Research Scientists And Development Engineers

- Three-time Best-Practice Partner by the American Productivity and Quality Center (APQC)
  - R&D Productivity
  - Leader in Innovation
  - Portfolio Management

- Carnegie Science Center Awards of Excellence
  - Corporate Innovation 2007
  - Advanced Manufacturing 2009
Global Industry Trends

Many Companies have **Cut Time to Market and Production Times / Costs by Half** and they will do it again…

- Near net shape workpieces
- Improved process capability
- Higher metal removal rates
- Multi-tasking machine tools
- Quick change tooling
- Cost per part contractual clauses
- Tooling ~ 3% of machining cost, significant leverage on the other ~ 97%

**A Must to Compete in Global Markets**
Global Industry Trends

- Globalization of Manufacturing
- Supply Chain Challenges
- Migration to Advanced Materials
- Energy Costs and Transportation
- Shortage of Metalworking Expertise

Challenges Compounded by the Economic Recession
Aerospace Industry Trends

Work-Piece Materials

– Shift to **Ti & CFRP** from Aluminum

– Landing gears, engines, …: **Titanium 5553**; higher strength (+25%), **New Hi-Temp Alloys**

– Frame: **Composites, sandwich materials** (Aluminum and/or Titanium plus Carbon Fibers)

*New Materials are Challenging the Limits of Traditional Processes*
Aerospace Trends – Titanium Machining

2x Growth driven by 2 factors:

– Average Ti content (weight) per aircraft to rise from 6% today to ~14% in next generation transports

– Aircraft demand forecasted to grow at 3~4% CAGR over the next decade

<table>
<thead>
<tr>
<th>Current</th>
<th>Next Gen</th>
<th>Aluminum</th>
<th>Composites</th>
<th>Titanium</th>
<th>Other</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>6%</td>
<td>10%</td>
<td>14%</td>
<td></td>
</tr>
<tr>
<td>70%</td>
<td>14%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16%</td>
<td>20%</td>
<td>50%</td>
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</table>

A Formidable Challenge for the Supply Chain
Lead Users Pointed out that Metal Removal Rate (MRR) for Aluminum went Down over the Years. Not so for Titanium... 2x Cost Down By 2010 is Required...
The Quest for Performance

Objective: Increase Tool Life > 3X at Current Conditions
• Thermal analysis of the metal cutting process led to a breakthrough tooling technology, which incorporates a coolant strategy into the tool holder and cutting insert.

• The technology dramatically improves tool performance for the manufacturing of aerospace components and structures made from advanced high temperature materials.

• Coolant delivery to interface
• Increased heat transfer
• Improved lubricity
• Increased productivity
• Increase MMR
• Increased tool life
• Improved chip control
Turning Tool Development

Titanium Machining

COOLTEKH™ Shows 50% Improvement Over Flood Coolant On Current Best In Class Technology.
**Cutting Conditions**
- Work piece: Ti6Al4V
- Hardness: 42 – 46 Rc
- Length of Pass: 254 mm (10 inch)
- Cutting Fluid: Water based synthetic

**Cutting Parameters**
- Cutting Speed: 58 m/min (187 sfm)
- Feed per tooth (hm): 0.18mm/tooth (0.007 ipt)
- Axial Depth of Cut = 2 mm (0.08 inch)
- Radial Depth of Cut = 81 mm (3.2 inch)

**COOLTEKH** is 300% Better Than Standard Coolant Delivery
## Impact of Geometry

### Current
**Operation / Part / Cut type:** Turn / Aerospace part / smooth cut  
**Grade:** KC5510  
**Insert:** ANSI RCGH43  
**ISO:** RCGH120400  
**Material:** Pre-machined R 56400 Titanium Alloy (3.7165)  
**Speed:** 185 sfm (56 m/min)  
**Feed:** .010 ipr. (0.25 mm)  
**Mean Depth of cut:** ~.080 inch (2.0 mm)  
**Length of cut:** 7.4 inch (188 mm)  
**Parts per edge:** 0.2  
**Chip Control:** Unsafe - poor chip control, sharp edges  
**Comments:** Acceptable surface finish  
**Cycle Time:** 143

### NEW Beyond Tool
**Grade:** KCS10  
**Insert:** RCGH43MP  
**ISO:** RCGH120400MP  
**Material:** Pre-machined R 56400 Titanium Alloy (3.7165)  
**Speed:** 205 sfm (62 m/min)  
**Feed:**  
**Mean Depth of cut:** .080+ inch (2.0 mm+)  
**Length of cut:**  
**Parts per edge:** 0.5  
**Chip Control:** Improved chip control, no sharp edges  
**Comments:** Best surface finish ever  
**Cycle Time:** 87

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The “Starburst Design” shows Improvements in Chip Control, Cycle Time, Tool Life, And Surface Finish
Importance of Integrated Tool Designs

Axial Seating Pin (first row pockets)
- Stronger axial support
- Increases chip flow area
- Easily replaceable
- Retaining screw same as insert screw
- More uniform insert spacing

Load Optimized Insert Spacing (LOIS)
- Angular row spacing optimized for uniform load distribution.
- Optimized for multiple axial engagements

Coolant Nozzles (all pockets)
- Precise consistent coolant delivery to all pockets
- Utilizes high-temp thread locking compound
- Smaller orifice sizes available
- Blank nozzles available to block unused pockets

Linear Movement Clearance
- Clearance allowed for up to .04 IPT (fz=1mm) when plunging or end milling
- Maximum allowable ramp angle

Without Nozzles

With Nozzles
**Innovations in Drilling**

**Test case:**
- Material: Duplex
- D = 8.5 mm
- l = 49 mm
- vc = 50 m/min
- f = 0.1 mm/rev
- Coolant: emulsion 5%, 20 bar

**Wear (after end of life)**
- Conventional SC-Drill: Chipping on margin land
- Y-TECH Drill: No chipping on margin land ("only" ordinary wear)

**3 Margins Design**

**Tool Life in Duplex**

<table>
<thead>
<tr>
<th>Number of Holes</th>
<th>Conventional</th>
<th>New Drill</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>250</td>
<td>750</td>
</tr>
<tr>
<td>250</td>
<td>500</td>
<td>1000</td>
</tr>
<tr>
<td>500</td>
<td>750</td>
<td>1250</td>
</tr>
<tr>
<td>750</td>
<td>1000</td>
<td></td>
</tr>
</tbody>
</table>

**Cylindricity**

<table>
<thead>
<tr>
<th>Cylindricity [mm]</th>
<th>Conventional</th>
<th>New Drill</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.02</td>
<td>0.04</td>
<td>0.06</td>
</tr>
<tr>
<td>0.04</td>
<td>0.06</td>
<td>0.08</td>
</tr>
<tr>
<td>0.06</td>
<td>0.08</td>
<td>0.10</td>
</tr>
<tr>
<td>0.08</td>
<td>0.10</td>
<td>0.12</td>
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</table>

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It’s Not Just About the Tools …

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

It Is About Partnerships, Digitization and Integration
An Aerospace Example

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>
</tr>
</thead>
<tbody>
<tr>
<td>Batch Size</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Number of Machines &amp; Spindles</td>
<td>4 &amp; 20</td>
<td>3 &amp; 3</td>
</tr>
<tr>
<td>Maximum Production Rate</td>
<td>1 part per day</td>
<td>2.5 parts per day</td>
</tr>
<tr>
<td>Total Flow Time</td>
<td>15.5 days</td>
<td>2 days</td>
</tr>
<tr>
<td>Work in Process</td>
<td>100 parts</td>
<td>7 parts</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Specialized</td>
<td>General</td>
</tr>
<tr>
<td>Return on Assets</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Safety / Ergonomics</td>
<td>High Risks</td>
<td>Low Risks</td>
</tr>
<tr>
<td>Floor Space / Machine Footprint</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>

**A 2.5x Performance Improvement**