Overview of Titanium Machining with Abrasive Waterjets

Mohamed Hashish
Flow International Corporation
www.Flowwaterjet.com
Waterjet Tools

Pure Waterjet

AWJ Process Parameters

Parameters
- Pressure
- Orifice size
- Mixing tube diameter
- Mixing tube length
- Abrasive material
- Abrasive particle size
- Standoff distance
- Traverse speed
- Jet lead angle

Results
- Roughness
- Waviness
- Kerf width
- Depth of cut

Titanium 2016, 25-28 Scottsdale, AZ USA
Waterjet Advantages

- Versatile for different materials and structures
- Capable of several features making
- No heat affected zones (HAZ)
- No distortion due to limited jet forces
- No delamination, splintering, fraying edges or any other integrity problems
- No subsequent processes are needed in many applications
- Reduced fixturing and tooling
- Lends itself to process automation and Robotics
- Clean, green, no material dust
- Potential higher productivity
Waterjet: Cut Attributes

Video

M. hashish • Flow

Titanium 2016, 25-28 Scottsdale, AZ USA
Titanium up to 18 inch thick has been cut with AWJ
More jet power is needed for efficient deep cutting
A large database exists as well as process models
Example: Rough Machining (IBRs and Blisks)

<table>
<thead>
<tr>
<th>Part</th>
<th>Blisk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>Titanium</td>
</tr>
<tr>
<td>Diameter</td>
<td>650 mm</td>
</tr>
<tr>
<td>Thickness</td>
<td>150 mm</td>
</tr>
<tr>
<td>Cycle Time</td>
<td>&lt;17 hours</td>
</tr>
</tbody>
</table>

- Gantry or robotic cells are used
- A turn table is used to index the part
- Proven process and is being used in production
- Enclosed cells with continuous waste management
- Temperature controlled cell and catcher
- Remote access for diagnostics

80% of material removed into segments not chips

Titanium 2016, 25-28 Scottsdale, AZ USA

M. Hashish  Flow
Example: LPT Gamma Ti/Al Blade Roughing

- Ingot dimensions: 2.07 x 2.07 x 9.35 inch
- Block dimensional tolerance: ± 0.02 inch
- Two blades are to be roughed out of one ingot block
- Over 75% of the material is saved – No chips
- Optimal AWJ cut roughness is used to minimize overall processing time
- A probe may be used to adjust for ingot shape inaccuracy and to determine optimal cut paths
- A robotic cell with a programmable indexer is used to rough the blades

M. hashish  Flow

Titanium 2016, 25-28 Scottsdale, AZ USA
Example: F22 Screens

- 35 Titanium screens with diamond-shaped holes (0.09 x 0.09 inch) ranging from 7000 to 30,000 holes per part
- Holes were drilled with AWJ using a 0.001 inch accurate system incorporating machine vision
- The vision system was used to inspect the hole geometry and location for compensation
- The screen drilling process has been in production for some 20 years
AWJ Hole Piercing Capability

- Diameter (d) ~ 0.015 inch - 0.060 inch
- Angle ~ 22 degree
- Size accuracy ~ 0.001 inch
- Spacing ~ d
- Depth ~ 25d
- Acoustic sensing is used to detect hole breakthrough

Video

M. hashish  Flow

Titanium 2016, 25-28 Scottsdale, AZ USA
Controlled Depth Milling Capability

- Capable of milling any material
- Milling to thin skins (0.5-mm) can be accomplished
- Surface finish of 4-6 microns can be obtained when using fine abrasives during the last passes of milling
- Depth uniformity to 25 microns
## Turning Capability

- Capable for turning difficult to machine materials such as aluminides and carbides
- Not all material need to be converted to chips
- Surface finish of 100 micro inch is typical with 60 mesh abrasives
- Large bars of Inconel have been sliced for forgings

<table>
<thead>
<tr>
<th>Turning Process</th>
<th>Turning Down from over sized shape</th>
<th>Spiral Turning</th>
<th>Shape Turning – One pass from Solid bar</th>
<th>Slicing methods and example</th>
</tr>
</thead>
</table>

Titanium 2016, 25-28 Scottsdale, AZ USA
Surface Effects

Peening

Coating Removal

Texturing

Deburring

M. hashish  Flow
Titanium 2016, 25-28 Scottsdale, AZ USA
Summary and Trends

- AWJ cutting of titanium is in production for many parts and gaining acceptance
- There is still low level of awareness about AWJ cutting capabilities
- More and periodic training is needed to maximize the benefits of waterjets for current users
- A Nadcap check list is in process for audit and more robust operations
Thank You

Questions Please

Mohamed Hashish

mhashish@flowcorp.com

Mobile: 206-465-5953