Flow's Aerospace Activity

Machining of CFRP with Water-Jets in Aerospace Industry

Ralf Moeller - Business Manager Aerospace - Europe
Flow's Involvement in Aerospace

Flow has sold CMC’s to most major aircraft programs using carbon fiber composites since 1984

- F117
- APACHE
- F18
- B2
- 777
- A340
- V22
- F18EF
- PREMIER
- F22
- CRJ
- A380
- 787
- GLOBALHAWK
- JSF
- A350XWB
- C Series

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Flow’s Involvement in Aerospace

FLOW is the ONLY water-jet / multi-process supplier to Boeing’s 787, Bombardier C Series and Airbus A350XWB program.
A350 XWB – Main Components

S11/12 Aerolia Meaulte

S13/14 Premium Aerotec Nordenham

S16/18 Airbus Stade

Keel Beam Nantes

S19 Airbus Illescas

Wing Cover Airbus Stade & Illescas Wing Spars GKN Filton
XXL Composite Machining

CMC’s - Twin Masts

- Side-fire
- Paser

- Drilling
- Routing
- Milling
- Probing
- Inspection
- Marking
A350 XWB – Trimming Solutions

**Wing Cover**
- Envelope: X = 37.5 m, Y = 7.5 m, Z = 1.5 m

**Fuselage Work**
- Envelope: X = 20.0 m, Y = 6.0 m, Z = 2.0 m

**Cockpit Work**
- Envelope: X = 6.0 m, Y = 6.0 m, Z = 2.0 m
Basics of the AWJ Process

AWJ = Abrasive Water Jet

• 4,140 bar water pressure
• Mixed with 80 - 120grit Garnet as an abrasive
• AWJ Stream is 1.1mm Diameter
• Cut with Velocity, not Pressure
• Super Sonic Erosion Process
  • “Vertical Grinding” at the Cut Edge
Basics of the AWJ process

- Orifice 0.25mm
- Jet monitor
- Abrasive in
- Pierce shield (optional)
- Mixing tube 1mm
- 4140 bar Water
- Intensifier Pump
Thick Composite Cutting

Comparison with traditional method:
- 3 x faster cut  @ 15% of the cost
Composite vs. Metal Routing

IN METAL CUTTING SHEAR FORCES
“PEAL” AWAY THE MATERIAL

IN PROPER COMPOSITE CUTTING
THE MATERIAL IS REMOVED BY FRACTURE
Composite Routing

During routing several types of damage can be introduced:
- matrix cracking,
- fiber pullout / fuzzing,
- interlaminar Cracks/delamination and
- Resin Melting.
Surface Finish Characteristics

- Routing of Carbon Fiber Composites

- 0 DEG PLY ORIENTATION
  POOR SURFACE FINISH, FIBERS TEND TO BUCKLE AND DELAMINATE

- 90 DEG PLY ORIENTATION
  GOOD SURFACE FINISH, NO DELAM.

- + 45 DEG PLY ORIENTATION
  POOR SURFACE FINISH, APPERANCE OF EXPOSED FIBERS OR ( WISKERS )

- - 45 DEG PLY ORIENTATION
  BAD SURFACE FINISH, ALWAY DELAMINATES
Surface Finish Characteristics

- Routing of Carbon Fiber Composites

• HEATED ZONE / RESIN MELT

  • RECAST AND MICRO-CRACK
  • DIRECTION OF TRAVEL
  • INTERNAL VOID
  • FIBER PULL OUT

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AWJ - COMPOSITE CUTTING ADVANTAGES Vs HIGH SPEED ROUTING

• MUCH BETTER FINISH – SURFACE SPEED MACH-3
• TOOL IS ALWAYS SHARP
• NO SECONDARY OPERATIONS REQUIRED
• NO MATERIAL DELAMINATION
• NO HEAT GENERATED
• NO AIRBORNE DUST
• MUCH LONGER TOOL LIFE
• LITTLE OR NO CUTTING FORCES OR VIBRATIONS
• SIMPLE FIXTURING - ¼ THE COST
• HIGHER FEEDRATES
• SINGLE PASS MACHINING FOR ROUGH AND FINISH PASSES
• COMPOSITE PARTS FAIL FASTER WHEN ROUTED
• MUCH LOWER OPERATION COST THAN ROUTING
Typical XXL Components

Examples:

- Wing: Covers, Wing Spars, Leading Edges, Flaps, Spoilers, Ailerons
- VTP & HTP: Covers, Rudder, Flaps, Leading Edges
- Fuselage: Panels, Stringers, Frames, Doors
- Keel Beam, Centre Wing Box, Belly Fairing
Typical Small Aerospace Parts

Examples:

- Clips, Ribs, Posts
- Brackets, Frames, Covers
- Typical Envelope Size: between 1x1m up to 2x7m
Standard Solutions

2D Systems:

• up to 6000 bar
• with DWJ and many more features (DCF, Laser Pointer etc.)
• work envelope from
  • 1,0 x 1,0 m to 6,0 x 4,0 m

• In Combination with 3D Robot Cutting (Future)
Standard Solutions

3D Systems:

• **Gantry Systems**
  
  Standard Work Envelope:
  2,4 m x 1,8 m resp. 3,6 m x 2,4 m

  or customized up to 30 m in length
Standard Solutions

3D Systems:

- Robot Cutting Cells
  - Stationary Jet
    - moving the part
  - Moving the Jet
    - stationary Part
- Combination of both with two Robots
Advanced Special Solutions

Multi Axis Systems:

• Bridge or Column Systems
  • Composite Machining Centers (CMC’s)
• Special Profile Cutters
• Stringer Trim System
XXL Composite Machining

CMC’s - Twin Masts

- Waterjet Mast
- Spindle Mast
- Side-fire
- Paser
- Drilling
- Routing
- Milling
- Probing
- Inspection
- Marking
6 - AXIS AWJ WRIST

“C” AXIS

“B” AXIS

“A” AXIS

AWJ NOZZLE

CATCHER CUP
Surface Preparation

- Removing of Paint with a Hand Tool
- Cleaning of Ships in a Dry-Dock
Flow Water-Jet Milling

CFRP

Ceramic

Glass

Inconel

Titanium
Flow  Water-Jet Milling

• Stainless Steel
• Depth: 50 mm
• Accuracy: 0,5 mm
Flow Water-Jet Milling

CFRP Repair (future):

• Remove Carbon Fibers
  • Layer by Layer
  • Accuracy 0,25 mm
WaterJet Physics

Sample Feed Rate [mm/min]

<table>
<thead>
<tr>
<th>Rate (mm/min)</th>
<th>Kerf (Taper) Angle</th>
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<tbody>
<tr>
<td>10</td>
<td>50</td>
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<tr>
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<td></td>
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<tr>
<td>50</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

- **Cutting**
  - Negative taper: much too slow
  - Best finish: too slow
  - Acceptable finish:
    - Speed
    - A - A
  - Poor finish:
    - Good speed
    - B - B
  - No through cut: too fast

- **Engraving**
Water Jet Physics

- Cutting → Engraving → Paint & Coat Removal → Milling

**Low Pressure**
- 800-1000 bar results in low Energy WJ Stream
- Nozzle Distance: 1-3 mm

**High Pressure**
- 4000-6000 bar results in Mach 3 WJ Stream
- Nozzle Distance: 1-3 mm

**Med. Pressure**
- 2800 bar results in med. Energy WJ Stream
- Nozzle Distance: 30-80 mm

**Low Pressure**
- 800-1000 bar results in low Energy WJ Stream
- Nozzle Distance: 5-8 mm
Water Jet Physics

• Milling Process by using Mask
Test Samples / Results

Platte 1 A, Ebene 2

Oberflächenprofil:

Draufsicht

Schnitt

Übergang Ebene 2 nach 3:

3D-Ansicht

oberer Radius: 300 μm
unterer Radius: 1 mm
Test Samples / Results

Platte 1 B, Ebene 2

Oberflächenprofil:

Draufsicht

Schnitt

Übergang
Ebene 2 nach 3:

3D-Ansicht

oberer Radius: 450 μm
unterer Radius: 800 μm
Test Samples / Photos
Flow Water-Jet Milling

CFRP Repair *(future)*:

- Remove Carbon Fibers
  - Layer by Layer
  - Accuracy 0,25 mm