RECENT DEVELOPMENTS IN THE FIELD OF AUTOMATED FIBER PLACEMENT FOR INDUSTRIAL APPLICATIONS

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Sept. 11th 2014, Munich
TUM - Lehrstuhl für Carbon Composites
Summary

I. Company Profile

II. Current Robotic Fiber Placement

III. Industry needs regarding AFP

IV. Coriolis recent development

V. Main challenges

VI. Conclusion
COMPANY PROFILE

**Founded in 2001**
• By 3 « young » engineers

**110 employes**
• Mostly engineers
• Highly skilled in robotics, composites & software

**Turnover 15M€**
• More than 20M€ expected in 2015

**French independant company**
• Founder owned

**Patented technology**
• 15 families of patent
• 150 titles

**References**
• Airbus Group (D&S, Aero) A350, Ariane 6, A320 NEO
• Safran (Aircelle), Dassault Aviation, Bombardier, Aerocomposit

[Company logos and branding images]
**Locations** : France, (Lorient, Biarritz) Germany (Augsburg), UK (Bristol), Canada (Montreal)

**Customers R&T lab** : TUM LCC (Munich, Germany), Compositadour (Biarritz, France), NLR (Holland), Fraunhofer (Germany), Univ. Perm (Russia), TPRC (Holland), Univ. Bristol (UK), Technocampus/IRT Jules Verne (Nantes, France)
COMPANY PROFILE

- Fibre feeding system with controlled temperature
- Standard high precision and high dynamic movement robot
- Proprietary software to control AFP robot
- Creel with tension regulated bobbin unwinding system
- Lightweight and highly innovative layup head, developed in-house

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COMPANY PROFILE

Robotic cells
• TP, dry/binder tow, Thermoset
• 8 to 32 tows

Software
• Integrated in CATIA V5/V6 or standalone
• Composites design, simulation and programing

Collaborative R&T
• Skilled engineer team
• Worldwide
Advanced Integrated composite Tail Cone project deals with aircraft composite structure development and production.
CURRENT ROBOTIC FIBER PLACEMENT

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CURRENT ROBOTIC FIBER PLACEMENT

- Head for 8/16/32 x ¼” or 8 x 1/8”
- Materials: thermoset, thermoplastic, dry binder yarn
- Heating: IR & Laser
- Independent Cut & Feed on the fly, $v_{max} = 1 \text{ m/s}$

Fiber optic cables from laser source

Optics

IR camera (option)

Fiber guidings

High temperature compaction roller

Layup direction
CURRENT ROBOTIC FIBER PLACEMENT

- No scrap
- High mechanical properties
- Variable thickness capability
- Control of compaction and consolidation
- Full simulation and off-line programming

*Inserts and variable thickness*

*No scrap when cut-outs*

*Steering*
INDUSTRY NEEDS REGARDING AFP

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## INDUSTRY NEEDS REGARDING AFP

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<tr>
<th>Industry</th>
<th>Aerospace</th>
<th>Industry</th>
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<tr>
<td><strong>Materials</strong></td>
<td>Thermoset Yarn</td>
<td>Dry fiber Yarn</td>
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<tr>
<td></td>
<td>Binder Yarn</td>
<td>Thermoplastics Yarn</td>
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<tr>
<td></td>
<td>Thermoplastics</td>
<td>Thermoset Yarn</td>
</tr>
<tr>
<td></td>
<td>50 to 100 €/kg</td>
<td>5 to 15€/kg</td>
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<tr>
<td><strong>Typical parts</strong></td>
<td>Fuselage + Door</td>
<td>Chassis</td>
</tr>
<tr>
<td></td>
<td>Tail cone</td>
<td>Body structure</td>
</tr>
<tr>
<td></td>
<td>Fairings</td>
<td>Spars</td>
</tr>
<tr>
<td><strong>Dimensions</strong></td>
<td>1 – 25 m</td>
<td>0.1 – 2.5 m</td>
</tr>
<tr>
<td><strong>Parts/Year</strong></td>
<td>100 - &gt; 2.000</td>
<td>1.000 - &gt; 200.000</td>
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<tr>
<td><strong>Features</strong></td>
<td>Double curved</td>
<td>Complex 3D</td>
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<tr>
<td></td>
<td>High quality</td>
<td>Variable thickness</td>
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<tr>
<td></td>
<td>Complex contour</td>
<td>Local reinforcements</td>
</tr>
<tr>
<td></td>
<td>Sandwich</td>
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**Flexible machine**  
**Precision**  
**Highly automated**  
**High productivity**  
**Low material costs**

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INDUSTRY NEEDS REGARDING AFP

- Low cost materials: direct roving or heavy tow + epoxy or PA
- No scrap
- Complex contours and variable thickness available
- Optimum fiber orientation
- Productivity of 1 part per minute (1 m² & 10 plies x 0.2 mm)
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RECENT DEVELOPEMENT

- Placement of multiple wide tapes to achieve high productivity
- Fiber placement machine & robot to produce 3D and 2.5D preforms without scrap
- Preform ready to be stamped or formed + injected
- Multi robot cell to increase productivity
- Large spool size
CRIOLIS RECENT DEVELOPMENT : DRY AFP

- Low cost dry heavy bindered tow : 50K or glass direct roving
- Binder compatible with epoxy or TP
- Optimization of the preform to reduce injection time

Benefits
- Low fiber cost compared to fabrics
- No more cutting table and waste management!
- Direct sourcing with raw material suppliers
- Complex contour and variable thickness
CORIOLIS RECENT DEVELOPMENT : THERMOPLASTIC

- Use of low cost thermoplastic tow preg based on 50K or 100K
- Complex preform ready to be stamped
- Compatible with PA6 and other resins

Benefits
- Quasi in-situ consolidation to avoid intermediate consolidation step
- Can be combined with thermoplastic over molding
- No scrap
- Complex contour and variable thickness
- No fiber fuzz
RECENT DEVELOPMENT : SIMULATION SOFTWARE

Automotive B-Pillar case study

- Infusion / RTM process simulation
- Curing/distortion
- Drapability analysis and ply boundary cuts preparation
- Forming process simulation: fiber orientation and wrinkling prediction
- Fiber placement process simulation: Tape courses and tows generation
- Structural analysis: Stress/failure, crash, fatigue, curing/distortion

Composites Design / ply book
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CHALLENGE: PRODUCTIVITY

- Continuous production without stopping the machine:
  - Heavy spools and automated off-line spool change without stopping the machine
  - Self-cleaning device to avoid machine stop due to jam and fiber fuzz
  - Automated preform transfer

- Optimize tape width and number of tapes placed simultaneously to maximize deposition rate
- Low material tension to maintain material integrity even at high speed and accel.
Direct roving preferred to slit tape to reduce costs, reduce fiber fuzz and improve mechanical properties

Consolidation between plies: matrix or binder formulation adapted to improve activation at low temperature

First ply adherence should not reduce layup speed but allow easy part release

Fiber stiffness and cohesion to prevent bulking & shearing of the preform during fast layup, even for thick laminates or curved paths

Material architecture optimized for forming and impregnation / infusion
CHALLENGE: FORMING

- Optimize the design the 2.5D preform regarding the 3D part to be formed
  - Partnership between Cadfiber (Coriolis fiber placement software) and Forming software to provide a numerical simulation chain from design to process
  - Export of accurate fiber orientations as input of the forming simulation
  - Import the forming simulation results back into AFP (bidirectional link)
  - Experimental study of forming of dry fiber and thermoplastics materials
  - Expert simulation: unidirectional fiber, accurate prediction of defects: fiber misalignments, wrinkles, fiber gaps/overlaps, optimization (preform layup and forming process parameters, design)
CHALLENGING PROJECTS

- German Collaborative project on production of composite automotive structures
- French collaborative project DEMOS with Faurecia
- 3DMAT: 3D forming simulation with ESI software
- TPRC membership – thermoplastic fiber placement, consolidation, forming and simulation
- NCC membership
- FIABILIN – flax and bio sourced matrix with Arkema
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CONCLUSION

Robotic AFP system provides:
• Full preform automation based on simple robotic system
• Minimal scrap
• 100% of the composite material is efficient

For high productivity requirements:
• Material behavior is the limiting factor for productivity
• Machine performance and material development have to progress in parallel
OTHER CHALLENGES?

Thank you for your attention.