Automated net-shape preforming of MAAXIMUS C73 frames

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Agenda

- Overview – MAAXIMUS project (DLR activities)
- Overview – MAAXIMUS work package C73 frames
- C73 frame: RTM process chain
- Automated net shape preforming process
- Achievements
- Conclusions & Outlook
Overview – MAAXIMUS project (DLR activities)

MAAXIMUS (More Affordable Aircraft through eXtended, Integrated and Mature nUmerical Sizing)

- Automated tape laying of shell on vertical tool
- Manual manufacturing of all stringers
- Co-bonding of cured stringers with a new inductive heating device
- Automated preforming of two C73 frames
Overview – MAAXIMUS work package C73 frames

Facts of both C73 frames of the MAAXIMUS panel
- Z-profile cross-section, approx. 1 m length
- Varying web height, varying flange width, several patches in inner flange and web
- Dry carbon and glass fiber woven fabric

Upper C73 frame

Lower C73 frame

Z-cross section  Constant width of outer flange

Varying width of inner flange

Varying height of web
Motivation

• Automated manufacturing of frames in an industrial environment

• Demonstration of a reproducible and robust process

• Flexible production line regarding different frame geometries

• Improved dimensional fidelity (spring-in compensated toolings)

• Less material waste (net-shape approach)
C73 frame: RTM process chain

Design

Curing process simulation

Preform Process

Quality Assurance

Injection & Curing

DLR.de • Chart 6 • Automated net-shape preforming of MAAXIMUS C73 frames • Björn Reinhard • SICOMP 01.06.2017
Video – Automated net shape preforming

If you are interested in the video please write me an email
Achievements - Preforming

- Successful manufacturing of 20 CFRP frames with one production line

- Process times
  - Ply preparation (one nesting) : 5 min
  - Preforming (one ply) : 4.5 min (Draping+QA+binder activation+QA)
  - Consolidation (whole preform) : 20 min
  - Fine trimming : 7 min

- Net shape fine trimming
  - Precise cutting edges, no fiber delamination
  - Local optimization of contour trimming could be realized

92 min for upper C73 (9 plies)
118 min for lower C73 (16 plies)
Achievements - Preforming

• Successful manufacturing of 20 CFRP frames with one production line

• Process times
  • Ply preparation (one nesting) : 5 min
  • Preforming (one ply) (Draping+QA+binder activation) : 45 min for upper C73 (9 plies)
  • Consolidation (whole preform) : 20 min
  • Fine trimming : 7 min

• Net shape fine trimming
  • Precise cutting edges, no fiber delamination
  • Local optimization of contour trimming could be realized

Time reduction of >25% can be realized by further optimization
Achievement - Preforming

Laser scan of the preform topology
- Target-performance comparison
- Deviations visualized by scaled bars

<table>
<thead>
<tr>
<th>Section 2</th>
<th>Measured and nominal geometry</th>
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<tbody>
<tr>
<td>Outer flange</td>
<td>Inner flange</td>
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<tr>
<th></th>
<th>Angle in [°] (Inner flange to web)</th>
<th>Angle in [°] (Outer flange to web)</th>
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<tbody>
<tr>
<td>Upper C73 (target: 90,7°)</td>
<td>100,5</td>
<td>109,8</td>
</tr>
<tr>
<td>Lower C73 (target: 90,7°)</td>
<td>99,0</td>
<td>104,1</td>
</tr>
</tbody>
</table>
Achievement - Preforming

Laser scan of the preform topology
• Target-performance comparison
• Deviations visualized by scaled bars

➢ Bulking analysis of different materials by different process parameters
Achievements – Injection and quality assurance

- Reduction of RTM process time by 60% by isothermal RTM process
- No findings in nondestructive testing (NDT) of all manufactured parts
- Geometrical shape verification of cured part in required space
- One set of C73 frames is installed in the test panel

![Inner Flange Spring-In-Angle Chart]

**Inner Flange Spring-In-Angle**

- Spring-In Angle
- Lower Bound
- Upper Bound
- Nominal Angle

Measurement Points: 1, 2, 3, 4, 5, 6, 7, 8, 9

Measurement Points: 89.5, 89.6, 89.7, 89.8, 89.9, 90.0, 90.1, 90.2, 90.3
Conclusions & Outlook

- Automated manufacturing of two different frames with one production line has been realized
- 20 net-shape preforms with no findings in NDT were manufactured
- Reduction of RTM process time by 60%
- Spring-in compensation strategy was successfully applied
  - Airbus tolerances were met for all frames

- Demonstration of the whole RTM production process (aircraft ribs)
- Bulking analysis of different materials with different process parameters
Thanks for your attention
Acknowledgements

• Martin Liebisch, Björn Reinhard: Automated, net shape preforming and isothermal injection process of spring in compensated frames. Springer. (will be published end of 2017)
• S. Torstrick, F. Kruse, M. Wiedemann: RTM-Processing for Net Shaped Parts in High Quantities. CFK Convention 2013, Stade, Germany
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• Martin Liebisch, Robert Hein, Tobias Wille: FE-based prediction of process induced distortions and residual stresses for cfrp frames. September 2015, Manchester, UK, 5th EASN International Workshop on Aerostructures.