Complex Multi-Textile Fibre Architectures

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Revealing Performance Advantages of Complex Architecture Multi-Textile Composite Lugs

Scope
Clearly demonstrate adoption of complex fibre architectures in a structural component, including validation of increased mechanical performance over typical, or baseline, manufacturing methods.

Original ALFET geometry
- NCF back-to-back L

Modified NEW geometry
- NCF back-to-back L
- 3D woven T
Materials

**NCF:** Sigmatex 400 gsm biaxial; T700S carbon

**3D woven:** Angle interlock equal warp/weft with 6% Z-fibre content; T700S carbon

Trimming performed by hand using bespoke jig

Preforms infused with Solvay Prism EP2400 at 120°C using VARTM
Mechanical testing

“Lug pull off” test was carried out on 14 parts using bespoke jig:
• 6 ALF NCF
• 5 NEW NCF
• 3 NEW 3D Woven

Imetrum non-contact video gauge recorded the test procedure using reference points on prepared surface:
Mechanical testing results

Typical load-displacement plots for all three types of lug architecture
In failure load, the 3D woven lug outperformed the same-shaped NCF lug.
In structural redundancy, the 3D woven lug outperformed both NCF lugs.
It is clear: tailored 3D fibre architecture can improve mechanical performance on complex shapes like these.
Bearing performance

Task: Assess the affect of through-thickness reinforcement on bearing load performance

8 400gsm plies of T700S carbon fibre biaxial Non-Crimp Fabric, vacuum infused with EP2400 epoxy resin at 120°C

- 1× 0/90 layup
- 1× QI layup (0/90/45/-45)
- 1× QI layup and 0.5% Areal Density (AD) 2×1k carbon tufts
- 1× QI layup and 2% Areal Density (AD) 2×1k carbon tufts

Coupons were prepared from the laminates and tested at Composite Test & Evaluation Ltd., Honiton, in accordance with ASTM D5961
Bearing test coupon quality assessment

- NDT inspection was performed on the non-tufted panels.
- Minimal loss in ultrasonic signal amplitude through the thickness of the part, and minimal variation in attenuation across the surface was detected, and it was considered acceptable to NCC quality standards and equivalent with minimal voidage.

- The tufted panels inspected by X-ray CT scan
- The 0.5% AD tufts were observed to have angled by 60°, and micro-voidage/cracking was observed
- The 2% AD tufts were nominally perpendicular, with the same micro-voidage/cracking

Above left: 0.5% AD tufts angled by 60°
Above right: Micro-voidage/cracking within tuft seam-side
Below left & right: Micro-voidage cracking
Bearing test results

- Tests were performed by Composite Test & Evaluation Ltd., Honiton, in accordance with ASTM D5961
- Strain was measured with an Imetrum Optical Video Monitoring System
- Testing was performed at a constant crosshead extension of 2mm/min until the load was found to drop by a minimum of 30% from the peak load
- All specimens failed by combination of laminate bearing, shear-out and cleavage failure modes

<table>
<thead>
<tr>
<th>Material configuration</th>
<th>Average specimen bearing failure strength (MPa)</th>
<th>Coefficient of Variation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0/90 – 0%</td>
<td>593.56</td>
<td>4.30</td>
</tr>
<tr>
<td>QI – 0%</td>
<td>675.05</td>
<td>5.26</td>
</tr>
<tr>
<td>QI – 0.5%</td>
<td>722.10</td>
<td>5.45</td>
</tr>
<tr>
<td>QI – 2%</td>
<td>698.92</td>
<td>1.08</td>
</tr>
</tbody>
</table>
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Project aim
Clearly demonstrate adoption of complex fibre architectures in a structural component, including validation of increased mechanical performance over typical, or baseline, manufacturing methods.

Project output
- 3D woven lug component produced superior pull out strength over the baseline
- 3D weaving reduced the size of the noodle and can lead to its complete removal with process optimisation
- Indications that the z-fibres reduce crack propagation
- Tufts may produce superior bearing strength results
- Complex loading needs to be explored to fully exploit the benefits of 3D woven material
- Identified challenges in sectors of the 3D weaving supply chain
Thank you
for your attention!

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