B6 Advanced Structure Design for Future Aircraft

Ecological and Multifunctional Composites for Application in Aircraft Interior and Secondary Structures

ECO-COMPASS
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Scientific & technical goals

- Natural Fibres?
- Bio-based resins?
- Recycled fibres?
- Multifunction?
Scientific & technical goals

- **ECO-COMPASS**
  - Ecological and Multifunctional Composites for Application in Aircraft Interior and Secondary Structures
- Cooperation of Chinese and European partners
- 2016 – 2019

- Identification of applications for eco- and multifunctional composites
- Development, characterization and simulation of eco-materials to give a broad overview of the possibilities in aviation with leverage to other transport sectors like automotive and railway
- Application / Demonstrators
- Life Cycle Assessment (LCA)
Main achieved and expected results

- **Improvement of fibre properties**

  Modification of sisal fiber with CNC by (a) electrophoresis, (b) electrostatic adsorption

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Diameter (µm)</th>
<th>Tensile strength (MPa)</th>
<th>Young’s Modulus (GPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated</td>
<td>173.3 (31)</td>
<td>529.9 (102)</td>
<td>13.6 (2.9)</td>
</tr>
<tr>
<td>CNC-treated</td>
<td>175.3 (32)</td>
<td>511.5 (97)</td>
<td>14.4 (3.3)</td>
</tr>
<tr>
<td>Alkali-treated</td>
<td>142.6 (18)</td>
<td>692.8 (92)</td>
<td>18.8 (3.0)</td>
</tr>
<tr>
<td>Alkali-CNC-EPD</td>
<td>156.4 (23)</td>
<td>614.9 (73)</td>
<td>22.0 (3.1)</td>
</tr>
<tr>
<td>Alkali-CNC-ESA</td>
<td>150.2 (20)</td>
<td>716.6 (110)</td>
<td>21.0 (2.6)</td>
</tr>
</tbody>
</table>

Main achieved and expected results

**Plasma treatment (rCF, flax)**

<table>
<thead>
<tr>
<th></th>
<th>Flexural Strength, 0° [MPa]</th>
</tr>
</thead>
<tbody>
<tr>
<td>rCF (no sizing)</td>
<td>200</td>
</tr>
<tr>
<td>rCF (no sizing)</td>
<td>300</td>
</tr>
<tr>
<td>rCF (no sizing)</td>
<td>350</td>
</tr>
<tr>
<td>rCF (no sizing)</td>
<td>250</td>
</tr>
<tr>
<td>rCF (no sizing) + Plasma300W</td>
<td>300</td>
</tr>
<tr>
<td>rCF (no sizing) + Plasma600W</td>
<td>350</td>
</tr>
<tr>
<td>rCF (with sizing)</td>
<td>300</td>
</tr>
</tbody>
</table>

**Hybrid nonwoven (rCF, flax)**

- Flexural Modulus in 0° [GPa]
  - Homogeneous hybrid: +59%
  - rCF in outer layers: +113%

Fibre volume content

30% Flax (Reference)
- 22.5% Flax + 7.5% rCF

"Plasma treatment of bio-based and recycled fibres for eco-composites",
R Garcia, LEITAT

Aerospace 2018, 5(4), 107; [https://doi.org/10.3390/aerospace5040107](https://doi.org/10.3390/aerospace5040107)
Aerospace 2018, 5(4), 120; [https://doi.org/10.3390/aerospace5040120](https://doi.org/10.3390/aerospace5040120)

Bucharest, 27-30 May 2019
Main achieved and expected results

<table>
<thead>
<tr>
<th>Natural oil based</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isosorbide based</td>
</tr>
<tr>
<td>Furan based</td>
</tr>
<tr>
<td>Natural Phenolic and Polyphenolic</td>
</tr>
<tr>
<td>Lignin derivatives</td>
</tr>
<tr>
<td>Rosin based</td>
</tr>
</tbody>
</table>

- Ding et al. 2015 [31] - n.o.b.
- Park et al. 2010 [114] - n.o.b.
- Park et al. 2010 [114] - p.c.
- Sudha et al. 2017 [41] - n.o.b.
- Deng et al. 2015 [61] - f.b.
- Deng et al. 2015 [61] - p.c.
- Deng et al. 2013 [111] - r.b.
- Li et al. [112] - r.b.
- Li et al. [112] - p.c.
- Hamerton and Mooring 2012 [10] - Cyanate ester
- Hamerton and Mooring 2012 [10] - Polybenzoxazine
- RTM 6 TDS [113]

Ramon, E.; Sguazzo, C.; Moreira, P.M.G.P. A Review of Recent Research on Bio-Based Epoxy Systems for Engineering Applications and Potentialities in the Aviation Sector. *Aerospace* 2018, 5, 110

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Main achieved and expected results

- **Rosin-based curing agent epoxy resin**

<table>
<thead>
<tr>
<th>Property and test condition</th>
<th>Unit</th>
<th>Reference</th>
<th>Test result</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength warp</td>
<td>RT/dry</td>
<td>MPa</td>
<td>≥500</td>
<td>707</td>
</tr>
<tr>
<td>Tensile modulus warp</td>
<td>RT/dry</td>
<td>GPa</td>
<td>65±8</td>
<td>62.3</td>
</tr>
<tr>
<td>Tensile strength weft</td>
<td>RT/dry</td>
<td>MPa</td>
<td>≥500</td>
<td>557</td>
</tr>
<tr>
<td>Tensile modulus weft</td>
<td>RT/dry</td>
<td>GPa</td>
<td>65±8</td>
<td>60.9</td>
</tr>
<tr>
<td>Compression strength warp</td>
<td>RT/dry</td>
<td>MPa</td>
<td>≥300</td>
<td>509</td>
</tr>
<tr>
<td>Compression modulus Warp</td>
<td>RT/dry</td>
<td>GPa</td>
<td>58±8</td>
<td>61.2</td>
</tr>
<tr>
<td>Compression strength Weft</td>
<td>RT/dry</td>
<td>MPa</td>
<td>≥280</td>
<td>362</td>
</tr>
<tr>
<td>Compression modulus weft</td>
<td>RT/dry</td>
<td>GPa</td>
<td>57±8</td>
<td>57.7</td>
</tr>
<tr>
<td>Bending strength warp</td>
<td>RT/dry</td>
<td>MPa</td>
<td>≥650</td>
<td>883</td>
</tr>
<tr>
<td>Bending modulus warp</td>
<td>RT/dry</td>
<td>GPa</td>
<td>58±8</td>
<td>56.8</td>
</tr>
<tr>
<td>Short beam shear strength</td>
<td>RT/dry</td>
<td>MPa</td>
<td>≥50</td>
<td>55.7</td>
</tr>
<tr>
<td>In plane shear strength</td>
<td>RT/dry</td>
<td>MPa</td>
<td>≥45</td>
<td>72.6</td>
</tr>
<tr>
<td>In plane shear modulus</td>
<td>RT/dry</td>
<td>GPa</td>
<td>3.5±1</td>
<td>3.84</td>
</tr>
</tbody>
</table>

1 A commercial product

Aerospace 2018, 5(2), 65; [https://doi.org/10.3390/aerospace5020065](https://doi.org/10.3390/aerospace5020065)
Aerospace 2018, 5(4), 110; [https://doi.org/10.3390/aerospace5040110](https://doi.org/10.3390/aerospace5040110)

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Main achieved and expected results

- **Flammability**

![Flammability tests](image)

- **Ramie + Epoxy (Reference)**
  - Flame Retardant
  - 27 sec

- **Ramie with Flame Retardant**
  - 12 sec

- **Epoxy with Flame Retardant**
  - 17 sec
  - 20 sec
  - 27 sec

Graph showing:
- Flammability acc. FAR25.853
- Requirement: Burn Length < 203 mm
- Requirement: After Flame Time < 15 seconds

**Bucharest, 27-30 May 2019**
Main achieved and expected results

AGMH-1 “Green Honeycomb” is made of plant fiber hybrid paper containing 20% plant fibers.

<table>
<thead>
<tr>
<th>Items</th>
<th>Compression strength, MPa</th>
<th>Longitudinal shear strength, MPa</th>
<th>Transversal shear strength, MPa</th>
<th>Longitudinal shear modulus, MPa</th>
<th>Transversal shear modulus, MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nomex, I</td>
<td>1.24</td>
<td>1.0</td>
<td>0.55</td>
<td>32.5</td>
<td>19.5</td>
</tr>
<tr>
<td>Nomex, II</td>
<td>1.64</td>
<td>1.07</td>
<td>0.58</td>
<td>36</td>
<td>19</td>
</tr>
<tr>
<td><strong>GREEN Honeycomb</strong></td>
<td><strong>1.78</strong></td>
<td><strong>1.16</strong></td>
<td><strong>0.75</strong></td>
<td><strong>43.2</strong></td>
<td><strong>29.3</strong></td>
</tr>
</tbody>
</table>

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Main achieved and expected results

- Modelling
Main achieved and expected results

**Electrical Conductivity Integration via InterWoven Wire Fabrics (IWWF)**

![Image of electrical conductivity integration via IWWF]

**Damage analysis CFRP lightning**

![Image of damage analysis for CFRP lightning]


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Potential gaps and challenges

- Fire resistance, especially the Heat Release of NFRP and (bio-based) epoxy resins.
- Long term behaviour
- Assessment of potential environmental impacts of treatments and processes to improve properties of eco-composites
Cross-cutting issues (tech. & non-tech.)

• Enhanced links between the European and Chinese entities contributing to the European initiatives in international cooperation
• Many open access publications which made the project data management “FAIR” (findable, accessible, interoperable and re-usable)
• Potential reduction of environmental impacts (e.g. global warming) during all life cycle phases
• Bio-based fibres and resins systems are promising materials for eco-composites in other transport sectors and industries. Successful use in demanding aviation could lead to increased use in other application areas
Impacts

- Reduction of environmental footprint by substitution of synthetic composite materials with bio-based and recycled materials.
  - Raw materials (and processes)
  - Fuel consumption during use-phase / lower density and multifunctional aspects.
  - End-of-Life recycling and energy recovery options
- Numerous publications, conference sessions and news articles
  - Special Sessions (ICCS, ICGC)
  - SCTS and Aerospace Special Issue (book)
  - Euronews „futuris“ film
Demonstrators

Airbus

AVIC

Bucharest, 27-30 May 2019
Useful infos and acknowledgements

TandemAerodays19.20
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