Polyfurfuryl alcohol based resins for fire resistant and high temperature applications

Hans Hoydonckx
Mathias Kelchtermans

SuCoHS Webinar

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TransFurans Chemicals

- World leading producer of furan chemicals located in Geel Belgium
- + 40 years of production of biomass based chemicals from agro-waste: Furfural and Furfuryl alcohol with annual capacity of 40 000MT.
- Full integration by the use of sugar cane bagasse produced by CRC (DR)
- Innovator in the development poly-FA as thermoset resin system.
Furfural Chemistry: Utilization of agrowaste as feedstock

- Sugarcane
- Sugar
- Bagasse
- Furfural
- Furfuryl alcohol

\[
\text{C}_6\text{H}_5\text{CHO} + \text{H}_2 \rightarrow \text{C}_5\text{H}_4\text{OCH}_2\text{OH}
\]
1. Acid catalyzed

2. Acid catalyzed

3. Acid catalyzed/temperature

Polyfurfuryl alcohol thermoset/ PFA

\[ \text{Polyfurfuryl alcohol} + \text{Water} \rightarrow \text{Polyfurfuryl alcohol thermoset} \]
Fire resistant composites in aerospace

PFA resins applied in form of prepregs

Various moulding techniques using:

• hot compression consolidation
• vacuum bag consolidation
• autoclave consolidation

• CF/PFA composites with enhanced fire performance
• High temperature performance
• Application in automated fiber placement

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CF/PFA composites with enhanced fire performance

- Modification PFA resin formulation for improved FR
- Strategy development for bottom-up evaluation thermal and fire resistant properties:
  - Thermal properties in oxidative atm. (TGA/DSC)
  - Cone calorimetry (a/t ISO 5660-1:2015 (50kW/m²)
  - FAR 25.853 (Appendix F Part IV(a) thru (h), 35 kW/m²)

- Increased peak temperature
- Increased degradation onset
- Decreased peakheight
- Decreased heat release
CF/PFA composites with enhanced fire performance

FR-PFA_1 has an effective decrease in peak heat release and total heat release compared to the reference material

<table>
<thead>
<tr>
<th>FAR 25.853 samples</th>
<th>Equipment</th>
<th># plies</th>
<th>Cure cycle</th>
<th>THR &lt; 65 kW.min/m²</th>
<th>PHR &lt; 65 kW/m²</th>
<th>Smoke Density &lt; 200 Ds</th>
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</thead>
<tbody>
<tr>
<td>PFA Ref.</td>
<td>Vacuum bag</td>
<td>12</td>
<td>2h at 95°C and 1h at 140°C</td>
<td>49,7</td>
<td>78,8</td>
<td>25</td>
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<td>PASS</td>
<td>FAIL</td>
<td>PASS</td>
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<tr>
<td>FR-PFA_1</td>
<td>Vacuum bag</td>
<td>12</td>
<td>2h at 95°C and 1h at 140°C</td>
<td>5.3</td>
<td>40</td>
<td>10</td>
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<td>PASS</td>
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<tr>
<td>FR-PFA_3</td>
<td>Vacuum bag</td>
<td>12</td>
<td>2h at 95°C and 1h at 140°C</td>
<td>29.6</td>
<td>100.6</td>
<td>17.4</td>
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<td>PASS</td>
<td>FAIL</td>
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</tbody>
</table>

FR-PFA_1 fulfills all requirements of FAR 25.853 (Appendix F Part IV(a) thru (h))
CF/PFA composites with enhanced fire performance

PFA Ref.  FR-PFA_1
High temperature performance

- Evolution of destructive to non-destructive analysis (SYN)
- Dynamic mechanical analysis (DMA) vs resistivity measurement

- No postcure: large influence of temperature on mechanical stiffness – presence of Tg
- Postcure 140-220°C: absence of large drop in the storage modulus – no obvious Tg but some residual postcure at high T
Application in automated fiber placement

Composite aircraft interior shell compliant to FAA regulations

Optimized fiber impregnation with FR-PFA formulations
Suitable tackiness achievable

Proven manufacturability of AFP processed PFA plates
Conclusions

• Modification of PFA resin to enhance FR properties

• FR-PFA_1 has an effective decrease in total heat release, peak heat release and increase in degradation onset.

• Fulfills FAA fire testing procedure FAR 25.853 (Appendix F Part IV(a) thru (h))

• Additional postcuring (> 140°C) eliminates the presence of an obvious Tg at high temperature

• Possibility of non-destructive online degree of cure and Tg monitoring using resistivity measurements

• Proven AFP compatibility of CF/PFA tape with enhanced fire performance
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