Atomic oxygen degradation mechanisms of epoxy composites for space applications

Yanjun He, Agnieszka Suliga*, Alex Brinkmeyer*, Mark Schenk, Ian Hamerton

* Oxford Space Systems, Electron Building, Harwell Space Cluster, Harwell, OX11 0QR, UK

bristol.ac.uk/composites
Overview of presentation

• Introduction

• Experimental and Test results

• Conclusions

• Future work
Introduction

- Space environment:
  - High vacuum
  - Extreme thermal cycling
  - Vacuum ultraviolet (VUV) radiation
  - Atomic oxygen (AO) erosion

- Work focus: AO behaviour of Thin laminate

Examples of composite in space made by OSS

OSS Composite Prototype Boom / Actuator
Objective

• Examine the AO resistance of three selected commercial thin composite materials

• Create a benchmark for the development of new matrix materials later in the project

Main tests:
• Three-point bend
• Surface Morphology
• Spectroscopy

<table>
<thead>
<tr>
<th>Exposure Cycle</th>
<th>Exposure duration (hr)</th>
<th>Total AO fluence ((\times10^{20} \text{atom/cm}^2))</th>
<th>Equivalent duration in orbit (days)†</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>1.75</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>2.82</td>
<td>31</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>3.82</td>
<td>43</td>
</tr>
</tbody>
</table>

† Based on the data from the International Space Station
## Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Laminate description</th>
<th>Lay-up (woven fabric)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAM 01</td>
<td>Carbon fibre reinforced epoxy resin A</td>
<td>(±45/0/±45) ‡</td>
</tr>
<tr>
<td>LAM 02</td>
<td>Carbon fibre reinforced epoxy resin B</td>
<td>(0/90)_3</td>
</tr>
<tr>
<td>LAM 03</td>
<td>Carbon fibre/Kevlar reinforced epoxy resin B</td>
<td>(±45/0/90/±45) *</td>
</tr>
</tbody>
</table>

* Kevlar in the middle ply and carbon fibre on top and bottom ply
‡ The middle ply is UD

Epoxy resin A

\[
\begin{align*}
\text{Epoxy resin B} & \quad \begin{array}{c}
\text{Epoxy resin B} \\
\end{array} \\
\end{align*}
\]
Three-point bending (3PB)

Epoxy resin A

Epoxy resin B

(a)  (b)  (c)
Surface Morphology

AO fluence = 3.82 × 10^{20} \text{ atom/cm}^2
Surface Morphology

Chemical structure of LAM 03

The surface morphology change of the LAM 03 after (a) first exposure, (b) second exposure, and (c) third exposure.
Spectroscopy
Conclusion

• Flexural properties of all laminates degraded after the first exposure

• LAM 01 shows an unexpected increase after the third exposure

• Surface resin has been gradually eroded after AO exposure

• AO has a different effect on the various chemical group of the resin
Future work

• Design a new resin system with improved AO resistance:
  - Materials selection
  - Baseline test
  - Exposure test
Thank you for listening
Any questions?

Email: yh15207@bristol.ac.uk

bristol.ac.uk/composites