Expansion of applying CFRP to aircraft

- Lightweight
- High strength
- High fatigue

Applying to aircraft

Struck by lightning

But...

Need to study the lightning damage of CFRP

Artificial lightning testing

Test condition

Discharge point

Copper jig

Specimen

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>IMS60/#132</th>
<th>IMS60/#133</th>
</tr>
</thead>
<tbody>
<tr>
<td>150 × 100 × 4.7 mm</td>
<td>14.9</td>
<td>16.6</td>
</tr>
<tr>
<td>Stacking sequence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[45/0°] × [45/90°]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Electrical Resistivity [Ωmm]

<table>
<thead>
<tr>
<th>Material</th>
<th>CFRP (Direction of thickness)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Duralumin</td>
</tr>
<tr>
<td></td>
<td>4.0 × 10⁻¹¹</td>
</tr>
<tr>
<td></td>
<td>7.3 × 10⁻¹</td>
</tr>
<tr>
<td></td>
<td>2.9 × 10⁻¹</td>
</tr>
</tbody>
</table>

Lightning protection system is required

Attaching metal mesh on CFRP to escape current

- Increase the manufacturing steps
- Weight increase etc...

But...

Need to study the lightning damage of CFRP

Coupled thermal–electrical analysis

Boundary condition

- Dimensions: 150 × 100 × 4 [mm]
- Stacking sequence: [45/0°] × [45/90°]
- Element type: hexahedron, 8 nodes
- Element count: 6000 nodes

Analysis results (Temperature distribution)

- High-temperature region increases
- Temperature does not rise to the transverse direction

Electrical breakdown

- Insulating state is destroyed by a high potential gradient
- Breakdown is one of the causes of gasification in the transverse direction

Test results

Resin gas

Gasification of the resin along transverse direction

Longitudinal: Fiber fracture
Transverse: Resin gasification

Electrical Conductivity

<table>
<thead>
<tr>
<th>Material</th>
<th>IMS60/#132</th>
<th>IMS60/#133</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitudinal</td>
<td>1.49</td>
<td>1.66</td>
</tr>
<tr>
<td>Transverse</td>
<td>1.38 × 10⁻³</td>
<td>6.93 × 10⁻⁴</td>
</tr>
<tr>
<td>Thickness</td>
<td>1.15 × 10⁻⁴</td>
<td>3.44 × 10⁻⁶</td>
</tr>
</tbody>
</table>

Ambient temperature 25 °C

Impulse current (40 kA, 8/20 µs / µs)

Discharge current

Electrical breakdown

Insulating state is destroyed by a high potential gradient

Breakdown is one of the causes of gasification in the transverse direction

Analysis results (Temperature distribution)

- High-temperature region increases
- Temperature does not rise to the transverse direction

Electrical breakdown

Insulating state is destroyed by a high potential gradient

Breakdown is one of the causes of gasification in the transverse direction

IMS60/#132

IMS60/#133

IPA

Effect of electrical properties on lightning damage behavior of CFRP

Ryuji Norota (Graduate Student of Tokyo University of Science), Yoshiyasu Hirano (Japan Aerospace Exploration Agency), Ryosuke Matsuzaki (Tokyo University of Science), Toshio Ogasawara (Japan Aerospace Exploration Agency)