Suppression of crack initiation for foam core sandwich panel joint

Yasuo Hirose

Kanazawa Institute of Technology

CDW-15 17-20 October, 2010
Contents

1. Background of our research
   Proposal of suitable structural concept for composite material

2. Results of foam core sandwich panel joint test
   Initial failure load, Failure mode, Failure mechanism

3. Analyses of test results
   Analyses of energy release rates, effect of impregnated resin

4. Proposal to enhance durability of foam core sandwich panel joint
   Suppression method of delamination onset
1. Background of this research

Figure 1: Trend of the fuselage structure.

- Structural concept of Boeing 777 fuselage.
- Stringer
- Skin
- Frame
- First flight: 1994
- Semimonocoque structural concept

- Composite fuselage demonstrator for Boeing 787.

- Structural concept of Japan Imperial Navy type 2 flying boat fuselage.
- First flight: 1940

Fig. 1 Trend of the fuselage structure.
A foam-core sandwich panel is one of suitable structural concepts for integral structures. Joint portion has an important role in the structural integrity. Tapered end closure type joint was selected considering visual inspection capability.

![Joint concept](image1.png)

![Foam core sandwich panel structure](image2.png)

**Fig. 2** Tapered end closure type joint
2. Results of foam core sandwich panel test

Fig. 3 Joint test specimen.
Joint strength test

Initial failure load: 39.2 kN.
Corresponding crack length: 7mm

Fig. 4 Joint test result.
3. Analyses of test results

Energy release rate at delamination end was calculated with FE analyses using FE model shown in Fig. 5.

Calculated energy release rate was compared with fracture toughness of $G_{IIc}$ to investigate the failure mechanism of the joint.

Simulated Delamination

Fig. 5 FE model to calculate the energy release rate.
Table 1 Analytical investigation.

<table>
<thead>
<tr>
<th>Energy release rate</th>
<th>Analytical results</th>
<th>Mechanical property</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 2</td>
<td>Model 3</td>
</tr>
<tr>
<td>G_I (kJ/m²)</td>
<td>0.06</td>
<td>0.06</td>
</tr>
<tr>
<td>G_II (kJ/m²)</td>
<td>2.12</td>
<td>1.53</td>
</tr>
</tbody>
</table>

Initial failure load: 39.4kN
Corresponding crack length: 7mm.

The $G_{II}$ values with this modified calculation agreed well with the $G_{IIC}$ value. The existence of resin impregnation at the tapered core edge much reduced the $G_{II}$ values.
\( \tau_{XY} \) distribution at initial fracture onset load of 39.2 kN


-Load redistribution was occurred at delamination end.
-This load redistribution reduced the energy release rate at delamination end.

Fig. 6 Comparison of shear stress distribution.
4. Proposal to suppress initial failure

The effect of filler mechanical property and size was estimated using FE model shown below.

Fig.7 FE model simulating filler size.
- The energy release rate decease as the shear modulus of the filler increases.  
- The filler with the mechanical properties of resin is enough to reduce the energy release rate.

**Fig. 8** The effect of the mechanical properties of the filler.
Fig. 9 indicates that relatively small area of the filler, such as 5mm from the tapered core edge, has enough effect on the energy release rate reduction.

![Graph showing the effect of filler size on energy release rate](image)

Fig. 9  The effect of the filler size.
Concluding remarks

- Failure mechanism of the tapered end closure joint was obtained through the joint test.
- The effect of the impregnated resin at the tapered core edge on the fracture onset was revealed by test results and related analyses.
- The idea to install resin filler at tapered core edge, crack arrester at joint, was proposed to retard the fracture onset in the joint portion.
- The effect of this arrester was analytically estimated.