CURE DEFORMATION ANALYSIS OF CURVED COMPOSITE HONEYCOMB SANDWICH STRUCTURE

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ABSTRACT
This work analyses cure deformation of a typical curved composite honeycomb sandwich structure. Cure deformations of composite faceplate and corresponding composite honeycomb sandwich structure were compared, and cure deformations of sandwich structure caused by co-cured temperature and faceplate ply misalignment were also numerical simulated. Composite samples were fabricated to validate the numerical predictions. The result of cure deformation analysis can confirm the validity of the forecast model and assess the degree of studied process impact on composite honeycomb sandwich structure.

Keywords: cure deformation, honeycomb sandwich structure, composite, finite element method, verification

INTRODUCTION
Integrated process is an important technique of cure process for composites to reduce parts and fasteners and meet the needs of structure performance. Fabrication cost can be reduced in integrated process. Cure-induced deformation of composite will have a very negative impact on the shape accuracy of composite component and the assemble match between the components, especially for large-scale and complex structural composite integrated structure, such as composite aircraft fuselage and wing.

It is well known that honeycomb sandwich structure is a common typical structure of composite component. It is important to guarantee a component and reduce fabrication cost that the method of analyzing deformation is developed for composite honeycomb sandwich structure.

A simplified multi level forecast model for cure process of a typical curved composite honeycomb sandwich structure was developed. Thermal deformation, cure shrink and the evolution of residual stresses in the entire cure process were considered in the model.

The studied sandwich structure, composed of composite faceplate and aluminum honeycomb, had a length of 400mm, with a radius of curvature of 165 mm. The thickness of faceplate and honeycomb were 0.8mm, 15mm respectively. The material for faceplate comprises of carbon-fiber fabric, pre-pregnated with a toughened epoxy resin. The type used here was T300/E602 and T300/E603 (fiber/resin). The reinforcement T300 was carbon-fiber fabric of Toray, and the epoxy resin E602 and E603 are both manufactured by our team. The validated composite structure samples were co-cured in an autoclave.
FINITE ELEMENT METHOD

The Finite Element analysis (FEA) is a powerful mathematical tool to solving partial differential equations for each element simultaneously. A specific model is applied to analyze cure deformation of a typical curved composite honeycomb sandwich structure. The graph of a relation for cure analysis model is shown in Fig.1. Material parameters of T300/E602, T300/E603 and aluminum honeycomb are measured, as shown in Table 1. Cure deformation of composite sandwich structure is characterized by maximum warping deformation and deformation curvature. The deformation degree of composite structure becomes larger with the increase of its maximum warping deformation. Maximum warping deformation is used as the characterization parameter of cure deformation in this paper.

![Graph of a relation for cure analysis model](image)

<table>
<thead>
<tr>
<th>Material</th>
<th>Elastic constant/GPa</th>
<th>Coefficient of thermal expansion/10*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>E1</td>
<td>E2</td>
</tr>
<tr>
<td>T300/E602</td>
<td>73</td>
<td>73</td>
</tr>
<tr>
<td>T300/E603</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>aluminum honeycomb</td>
<td>0.069</td>
<td>0.069</td>
</tr>
</tbody>
</table>

PS: T300/E602 and T300/E603 are carbon-fiber fabric reinforce epoxy resin composite.

Curved faceplate and curved sandwich structure are compared, and then cure deformation of the curved composite sandwich structure considering co-cured temperature and faceplate ply misalignment are analyzed. The two cure temperature are 130°C and 180°C respectively, and
faceplate ply misalignment is 10°. And to verify the simulation rule of the curved composite honeycomb sandwich structure, we fabricated and tested several carbon-fiber composite samples. CFRP composite samples were fabricated through autoclave molding process.

RESULTS

The result from cure deformation analysis of the curved faceplate is shown in Fig.2, and the predictions of the curved composite sandwich structure considering co-cured temperature and faceplate ply misalignment are shown in Fig.3-Fig.5. Faceplate plies misalignment only happen in the process state of Fig.5. Validated samples of sandwich structure are shown in Fig.6. Deformation amount of samples were characterized by using a level ruler to measure the 1/4 circle corresponding chord length of curved samples (in Fig.7). Table 2 shows the results of simulated deformations and validated measurements with different analysis conditions. Deformations of curved honeycomb sandwich structure are much smaller than that of the faceplate, that is, the sandwich structure can effectively inhibit cure deformation of composite component.

![Fig. 2 - Predicted deformation of curved faceplate](image1)

![Fig. 3 - Predicted deformation of curved sandwich structure(cured at 180°C)](image2)

![Fig. 4 - Predicted deformation of curved sandwich (cured at 130°C)](image3)

![Fig. 5 - Predicted deformation of curved sandwich (cured at 130°C, faceplate plies misaligned by 10°)](image4)

![Fig. 6 - Validated samples of sandwich structure](image5)

![Fig. 7 - Measuring the 1/4 circle corresponding chord length of curved sample](image6)
Table 2 - Simulated deformation and validated measurements with different analysis conditions

<table>
<thead>
<tr>
<th>Analysis Condition</th>
<th>Simulated Deformation [mm]</th>
<th>Validated Measurement [mm]</th>
<th>Deviation [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curved Faceplate</td>
<td>28.2</td>
<td>29</td>
<td>2.8</td>
</tr>
<tr>
<td>Curved Sandwich Structure (cured at 180ºC)</td>
<td>1.04</td>
<td>1.03</td>
<td>1.2</td>
</tr>
<tr>
<td>Curved Sandwich Structure (cured at 130ºC)</td>
<td>0.864</td>
<td>0.85</td>
<td>1.6</td>
</tr>
<tr>
<td>Curved Sandwich Structure (cured at 130ºC, faceplate plies misaligned by 10º)</td>
<td>0.891</td>
<td>0.88</td>
<td>1.3</td>
</tr>
</tbody>
</table>

CONCLUSIONS
This study shows that numerical predictions compared quite well with experimental measurements for the cure-induced deformations. The influence of the co-cured temperature on cure deformation of composite honeycomb sandwich structure is significant, while the contribution of faceplate ply misalignment to cure deformation is small. Further study should be performed in order to analyze other factors on deformation of curved composite honeycomb sandwich structure, such as height of honeycomb, thickness of faceplate.

REFERENCES