Comparative discussion about impact damage of CFRP laminates with two types of different ply-thickness

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Thin-ply laminate

- Although there is no clear definition of the thickness of “thin-ply”, it is generally around 40 to 50 $\mu$m.
- Features of “thin-ply” laminates;
  - Increase of tensile strength \(^1\)
  - Increase of compressive strength \(^2\)
  - Suppression of microcracking \(^1\)


(Adapted from 1))

Fig. 7. Stress-strain curves of Qi THIN and THICK laminates under UNT static loading. Strains were measured in the middle of specimen.

(Adapted from 2))
Impact damage on thin-ply laminates

- Projected delamination areas are almost same between Thick and Thin.\(^1,3\)\)
- CAI strength of Thin was slightly higher than that of Thick.\(^1,3\)\)

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Inside damages observed by ultrasonic scanning

Thick

- Hole edge of fixture
- Impact side
- Side view
- Back side

Thin

- Impact side
- Side view
- Back side
- Midplane

In our study, however, projected damage area was almost same, the distribution of damage through-thickness direction was quite different.
Objective

The objective of this study is to clarify what happened inside “thin-ply” laminates after impact loading.

- Damage distribution maps were developed by precise observations of cross-sections in both Thin and Thick laminates.

- Based on the damage map, damage processes of both Thin and Thick laminates were estimated under impact loading.
## Materials

<table>
<thead>
<tr>
<th></th>
<th>Thick</th>
<th>Thin</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Materials</strong></td>
<td>TR50S/#350 prepreg (Mitsubishi Rayon Co., Ltd.)</td>
<td></td>
</tr>
<tr>
<td><strong>Ply thickness</strong></td>
<td>147 mm</td>
<td>38 mm</td>
</tr>
<tr>
<td><strong>Stacking sequence</strong></td>
<td>[45/0/-45/90]$_{3S}$</td>
<td>[45/0/-45/90]$_{12S}$</td>
</tr>
<tr>
<td><strong>Thickness of laminate</strong></td>
<td>3.44 mm</td>
<td>3.50 mm</td>
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</table>
Test conditions of impact loading

- Specimens were fixed by two steel plates which had cutout hole of 30[mm] in diameter.

- Impact energy: 0.75[J/mm]
  - Barely visible damage level
- Diameter of impactor: 16[mm]
- Weight of impactor: 0.998[kg]
CAI strength

- CAI strength of Thin was slightly lower (6%) than that of Thick.
- Failure morphology was almost same in both Thick and Thin.
Delamination was generated ranging over multiple interlaminar in Thick specimen.

Wide-spread delamination was confirmed only in the middle layer in Thin specimen.

- In extended figure, many transverse-cracks were observed in Thick specimen.
- On the other hand, few transverse-cracks were confirmed in Thin specimen.
Damage distribution map

Since whole 3-D map of internal damage was too complicated, only the midplane part was picked up for Thick and Thin, respectively.

These transverse cracks connected neighboring delamination. Therefore these internal damage formed helical shape in Thick specimen.

However the size of delamination has large scatter in Thin, internal damage formed helical shape as well as Thick specimen.

Thus, 3-D internal damage maps were successfully constructed in Thick and Thin laminate.
Discussion of observation result

We focused on transverse crack.

Transverse cracks occur in almost all layers in Thick specimen, and it seems that delamination was formed between adjacent transverse cracks. On the other hand, the number of transverse cracks were very small in Thin specimen. And it is suggested that large propagation of delamination was caused by the absent of transverse crack as shown in this 3-D model.

Therefore, it is considered that transverse crack decides the geometry of delamination in Thick and Thin specimens.
Assumption of impact damage process

Based on these observation results, assumed damage process in shown as follows.

① Transverse-cracks were formed in multiple layers when impact was applied to specimens.

② Delaminations were formed starting from where transverse cracks reached interlaminar.

In the case of Thin, transverse cracks are less number than Thick specimen.2)3)

It is considered that the number of transverse cracks affect distribution of internal damage.

2) T. Yokozeki, Composite Structures, 82, 2008, pp.382-389
CONCLUSIONS

3-D internal damage map was developed in Thick-ply and Thin-ply laminate. (This model was obtained by the integration method in which damages observed in cross-sections were integrated.)

It is considered that transverse crack decides the geometry of delamination in Thick and Thin specimens.

Outlook

We examine the incidence which is the transverse-cracking mechanism.