Open-hole Response of Pseudo-ductile Thin-ply Angle-ply Laminates

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Introduction

Pseudo-ductile tensile stress-strain responses have been achieved by using thin-ply angle-ply with central unidirectional plies concept.

\[ [\pm \theta_n/0_m]_s \]

Standard modulus

Standard/high modulus

Key challenges:

- Understand the mechanism of pseudo-ductile thin-ply angle-ply under open-hole tension
- Design the laminate with reduced notch-sensitivity
Open-hole testing – General Behaviour

(±26_s,0)_s

T300 – standard Modulus fibre

T300 – standard Modulus fibre

Notch Sensitive

(±25_s,0)_s

MR60 Intermediate modulus fibre

YSH70A high modulus fibre

Notch Insensitive

Modulus:
- 58 GPa (Open-hole)
- 57 GPa (Unnotched)

Modulus:
- 121 GPa (Open-hole)
- 130 GPa (Unnotched)

Initial strain 1

Pseudo-ductile strain 1

Initial strain 1

Pseudo-ductile strain 3.5

Net-section strength: 520 MPa, 65% of unnotched yield strength.

Net-section strength: 620 MPa, 96% of unnotched yield strength,
Damage Characterization - DIC

USN-USN
(±26_{5,0})_s
Notch-sensitive
USN: T300 standard
Modulus fibre

UIN-YSH
(±25_{2,0})_s
Notch-insensitive
UIN: MR60 Intermediate
modulus fibre
YSH: YSH70A high
modulus fibre
Conclusions

• Main governing factor in open-hole performance – Pseudo-ductile strain to Initial strain ratio.
  a) Low strain ratio: linear response, 35% yield strength reduction and notch sensitive.
  b) High strain ratio: non-linear response, retain all the yield strength and notch insensitive.

• Fragmentation and dispersed delamination mechanism help in reducing the stress concentration around hole and redistribute the strain.

• Potential to achieve pseudo-ductile stress-strain behaviour under open-hole tension loading with proper selection of strain ratio.
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The aim of this study is to experimentally investigate the open-hole tensile response of pseudo-ductile thin-ply angle-ply laminates. It is shown that with proper selection of pseudo-ductile strain to initial strain ratio, notch sensitivity is reduced and at least 90% of unnotched yield strength can be attained.

Background:
Pseudo-ductile tensile stress-strain responses have been achieved in using thin-ply angle-ply with central unidirectional glass composite. Periodic fibre fragmentation in the central 0°-plies and their dispersed local delamination introduce pseudo-ductile strains.

Initial Design:
- Sky faces (12.5 mm) with layers (±25,0°)
- Pseudo-ductile to initial strain ratio 1
- Attained 6% unnotched yield strength
- Brittle notched failure
- Insufficient stress and strain distribution

Improved Design:
- Angle-ply (Sky faces, UD and 0°) and UD ply (Y81T8) with layers (±25,0°)
- Pseudo-ductile to initial strain ratio 2.5
- Attained 94% unnotched yield strength
- Non-linear stress-strain response observed
- Fragmented central UD plies and dispersed delamination released stress concentration and redistributed strain

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