Composite Structures
– some basic issues and principles

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Questions include....

- Don’t impact damage and defects design all composite structure?
- Surely you want better resolution, find smaller and smaller defects?
- Why do quite small defects matter a lot in some areas while you will accept large defects in other areas?
- Why doesn’t fatigue matter so much in composites?

So what actually designs the composite structure....?
• Strength/ stiffness varies with layup
  • Carpet plots, above shows tension strength
  • Similar plots in
    • compression, shear etc
    • Strength / stiffness
    • Plain/ notched etc
Skin panel layup

- Test panel representing small area of a skin
- Shows multiple changes thickness/ layup
- Large skin can easily have 150+ “zones”
Carpet plots for strength and stiffness basically same shape
- Strain to failure (Strength/modulus) is approx. constant
- For large area design, unnotched areas of skin
- Measured in microstrain \((1 \mu \varepsilon = 10^{-6})\)

- Unnotched tension strain to failure - typically 15 000\(\mu \varepsilon\) \((= 0.015)\)
- Unnotched compression strain to failure - typically 10 000\(\mu \varepsilon\) \((= 0.010)\)
Effect of holes in composites

Local stress concentration at edge of hole:
• theoretically 3.0 for isotropic material

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<tr>
<th></th>
<th>Metals</th>
<th>Composites</th>
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<tbody>
<tr>
<td>Statically</td>
<td>• Plasticity round hole</td>
<td>• Elastic to failure</td>
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<tr>
<td></td>
<td>• Eliminates stress concentration</td>
<td>• See full stress concentration</td>
</tr>
<tr>
<td>Fatigue</td>
<td>• See full stress concentration</td>
<td>• Already designed for stress concentration</td>
</tr>
<tr>
<td></td>
<td>• Fatigue prone</td>
<td>• Fatigue usually generally not an issue</td>
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- **Composites:**
  - typically 2.5 in tension
  - slightly less in compression
  - due to slight local damage/softening around hole

- Notched strain to failure
  - Tension - typically 5500με
  - Compression - typically 4500με

- **Always have to allow that hole may occur anywhere**
Effect of Holes and Impact Damage on Laminate Strength

**TENSION**
- Holes larger effect than impact damage
- Design to “hole”

**COMPRESSION**
- Impact damage larger effect than holes
- Design to impact damage
Detectability requirements
- usually visual
  - BVID
  - CVID

Impact – Effect of thickness

Detectability requirements for the selected inspection procedure.

Energy level that can be realistically expected from manufacturing and service.

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Typical Military Aircraft Wing skin

Typically 40% 0° in local reinforcement

Typically 60% 0° along root rib, 12-20mm

Local reinforcement around cut outs and leading / trailing edges

General skin areas reduce from typically:
- about 50% 0°, 10mm thick at root to
- 25% 0°, 3mm thick at tip

So what designs these areas/ determines these thicknesses?
Wing design

Upper wing skin – compression dominated

Lower wing skin – tension dominated (spectrum inverted)

- Different aspects dominate design of upper and lower skins
Upper wing skin – compression dominated

- Wing pick up / carry through
  - Local load inputs
  - Bearing/ compression
  - Local reinforcement

- Outboard skin panels
  - Thin
  - Buckling designed
  - Limits strains

- Other skin panels
  - CAI - Typically 4500 με

- Ribs/ spars locations
  - Local reinforcement
    - Local load inputs
    - Stress concentrations

Designed typically:
- 40% bearing/ notched compression strength
- 30% stiffness and buckling
- 30% Compression after impact

Other aircraft – different roles eg large civil- similar issues/ different percentages
Lower wing skin – tension dominated

- Wing pick up / carry through
  - Local load inputs
  - Local reinforcement
- Tension/bearing

- Skin panels designed
  - Allowable notched tension strain - typically 5500 μe
  - General allowable design strain to accommodate hole anywhere

Designed typically:
- 40% bearing
- 40% notched tension
- 20% stiffness
Thin skin stiffened panels

- Smaller control surfaces
- Access panels etc
- Small doors

- Skin thicknesses maybe as low as 0.75mm
- Impact damage at low impact energies
- Allow impact on bondlines
- Design strains can be reduced to typically 2000µe

Thin skinned honeycomb or foam cores

Bonded stiffeners
Summary

• Holes and impact damage major reduction in strength
  • Generally holes more severe in tension
  • Impact more severe in compression
• Design to allow for 6mm hole anywhere
• Design around damage - visual detectability
  • Not worth chasing smaller and smaller defects
• Composite structure - multiple design criteria
  • Defects are not dominant design criteria in all areas