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Elastic Tailoring of Composite Structures by Fibre Steering

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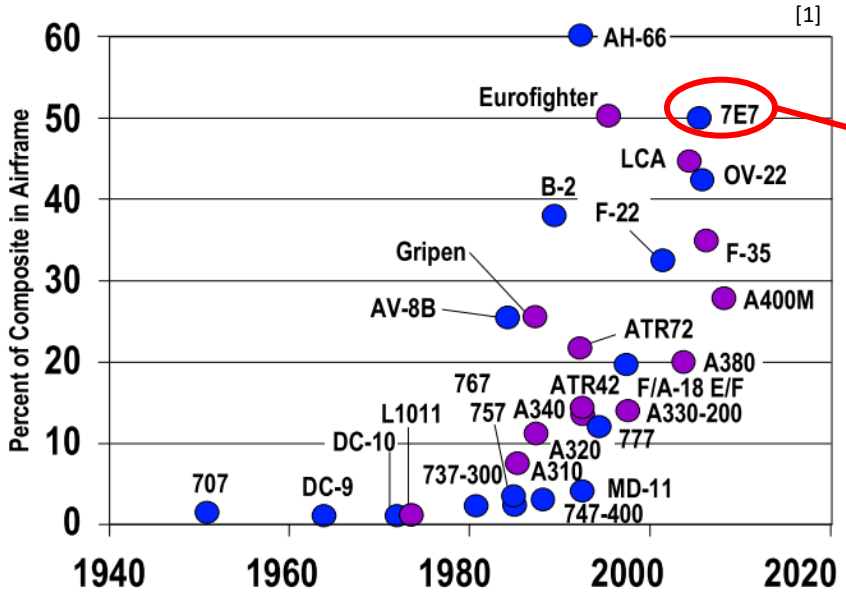
Motivation: Lightweight Aerospace Structures

- Increasing use of advanced composites in aerospace structures
- **Mass efficiency is a key design driver**
  - Larger payload capacity
  - Lower fuel burn
  - Enable new economic opportunities

[1]



Increasing Use of Advanced Composites in Aerospace

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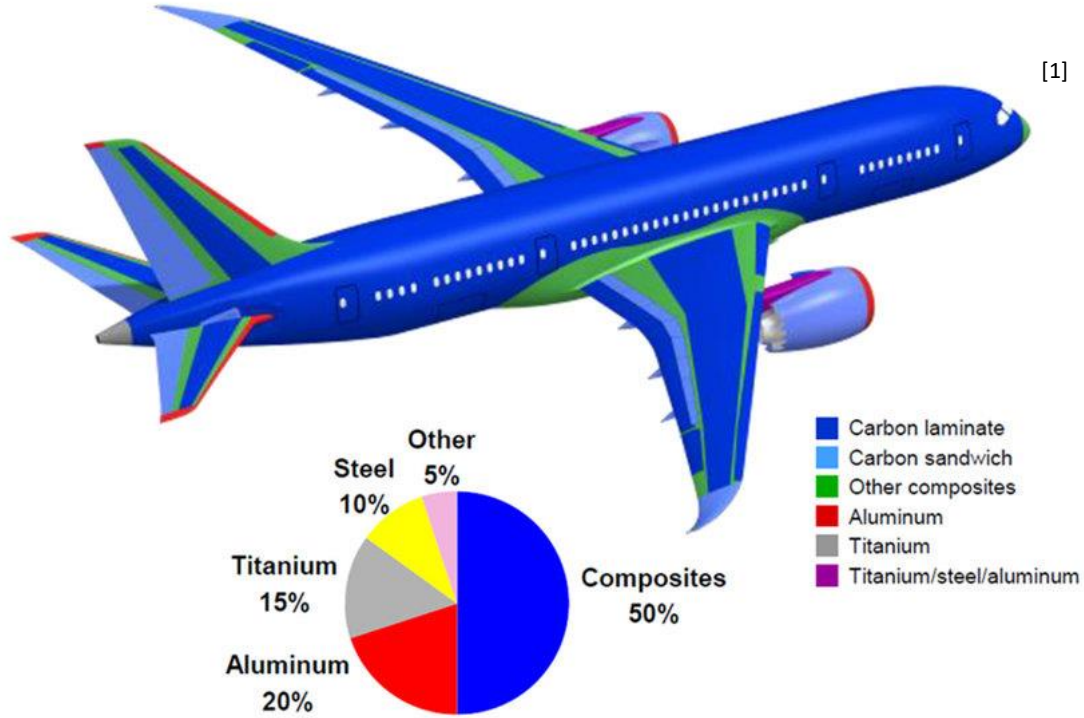
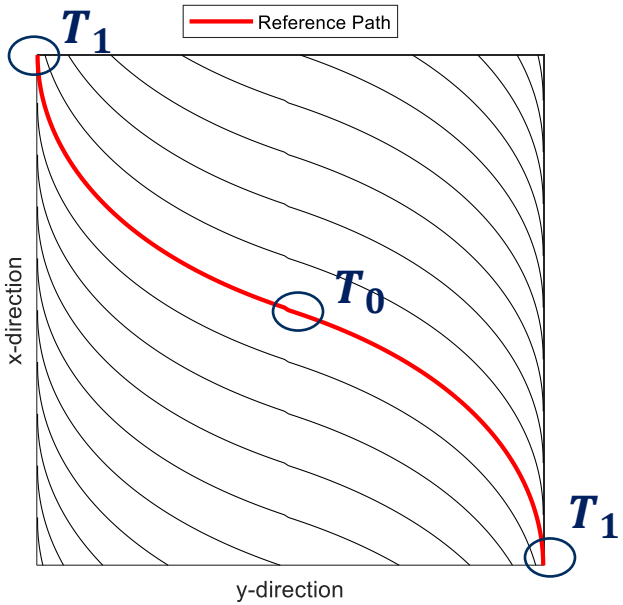


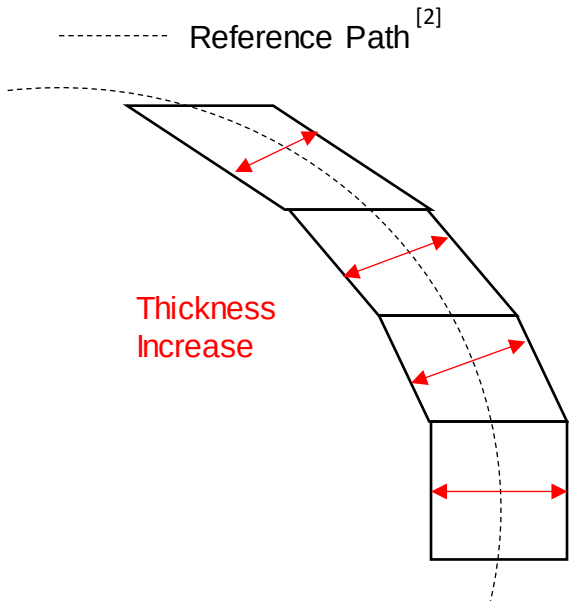
Boeing 7E7 Dreamliner Material Use

Context: Fibre-Steered Composites

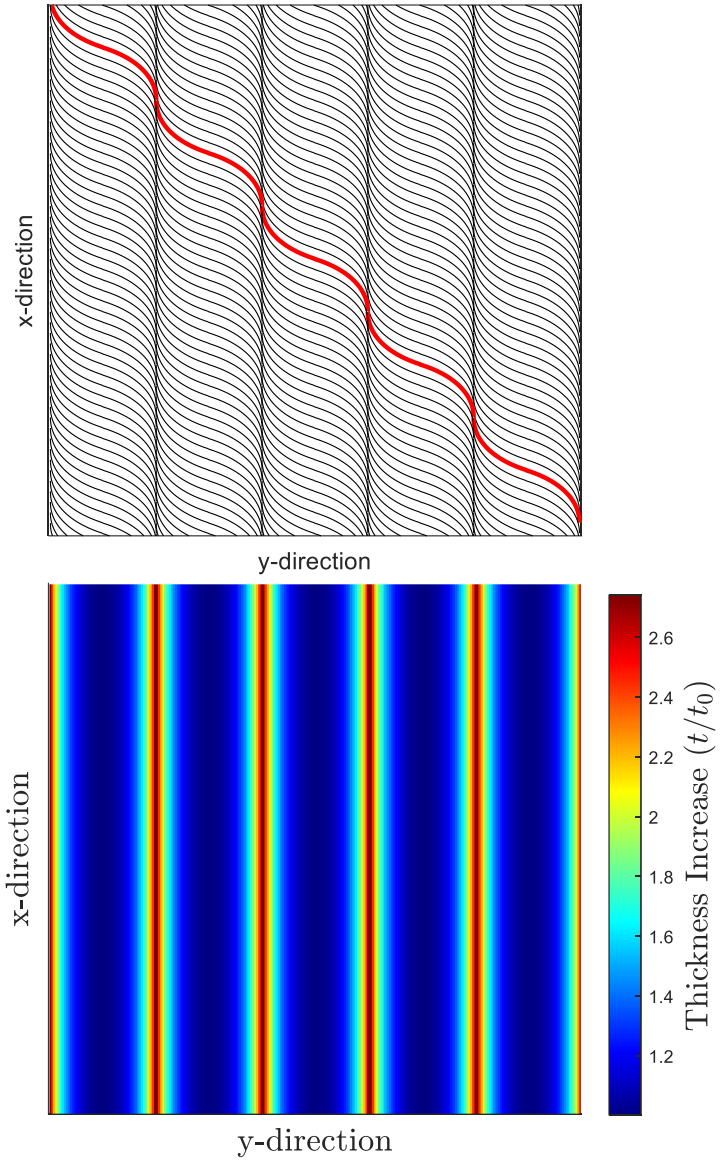
- Steering of composite material tapes produces **non-constant fibre angle across a ply** to redirect load paths and tailor performance
- **In-plane shearing of material tows by Continuous Tow Shearing (CTS)** process along curvilinear reference eliminates potential defects and allows tessellation
- CTS process exhibits **nonlinear orientation-thickness coupling** and allows **periodic fibre steering**



State-of-the-Art Fibre-Steered Ply



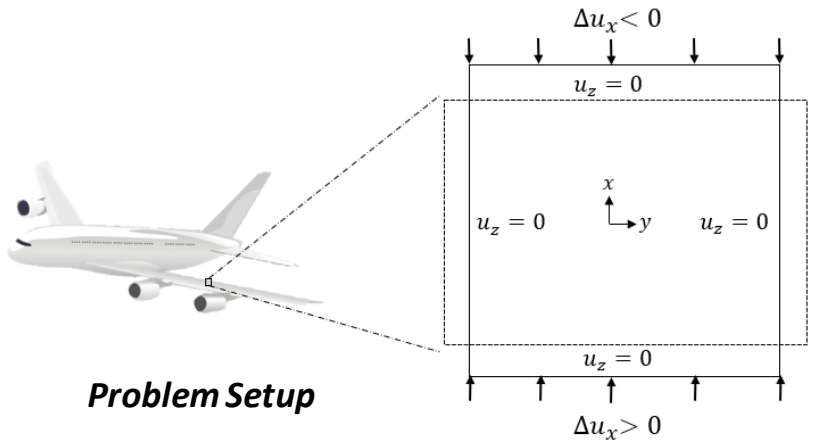
CTS Material Deformation



Enabling Periodic Fibre Steering

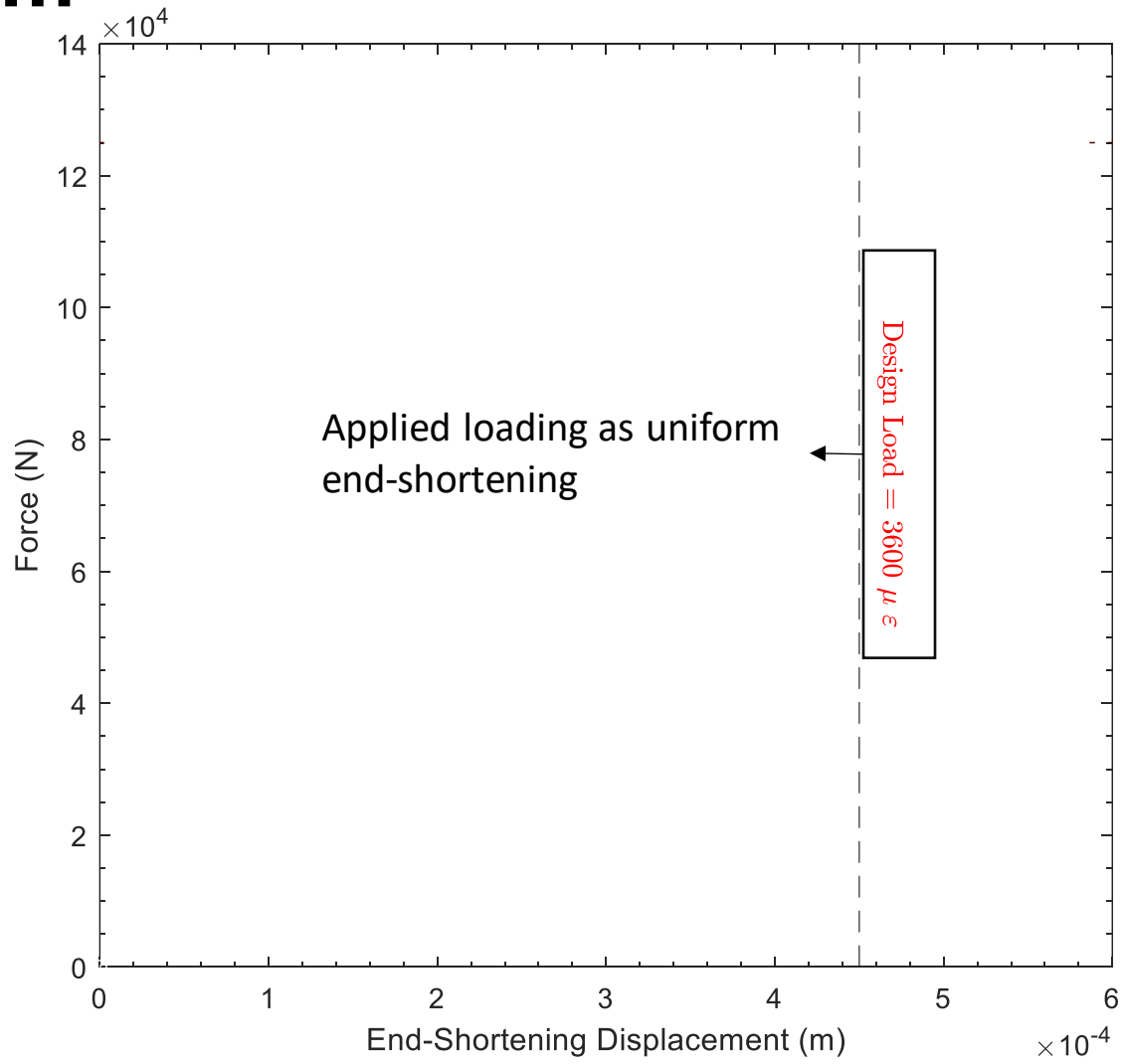
Methodology: Structural Problem

- Application
  - Common aerospace problem of **simply supported panel under uniaxial compression**



Problem Setup

- Hypothesis
  - Can a novel fibre-steered panel have a **greater load carrying** capacity than a conventional straight fibre panel?
- Constraints
  - Enforce ‘design’ load



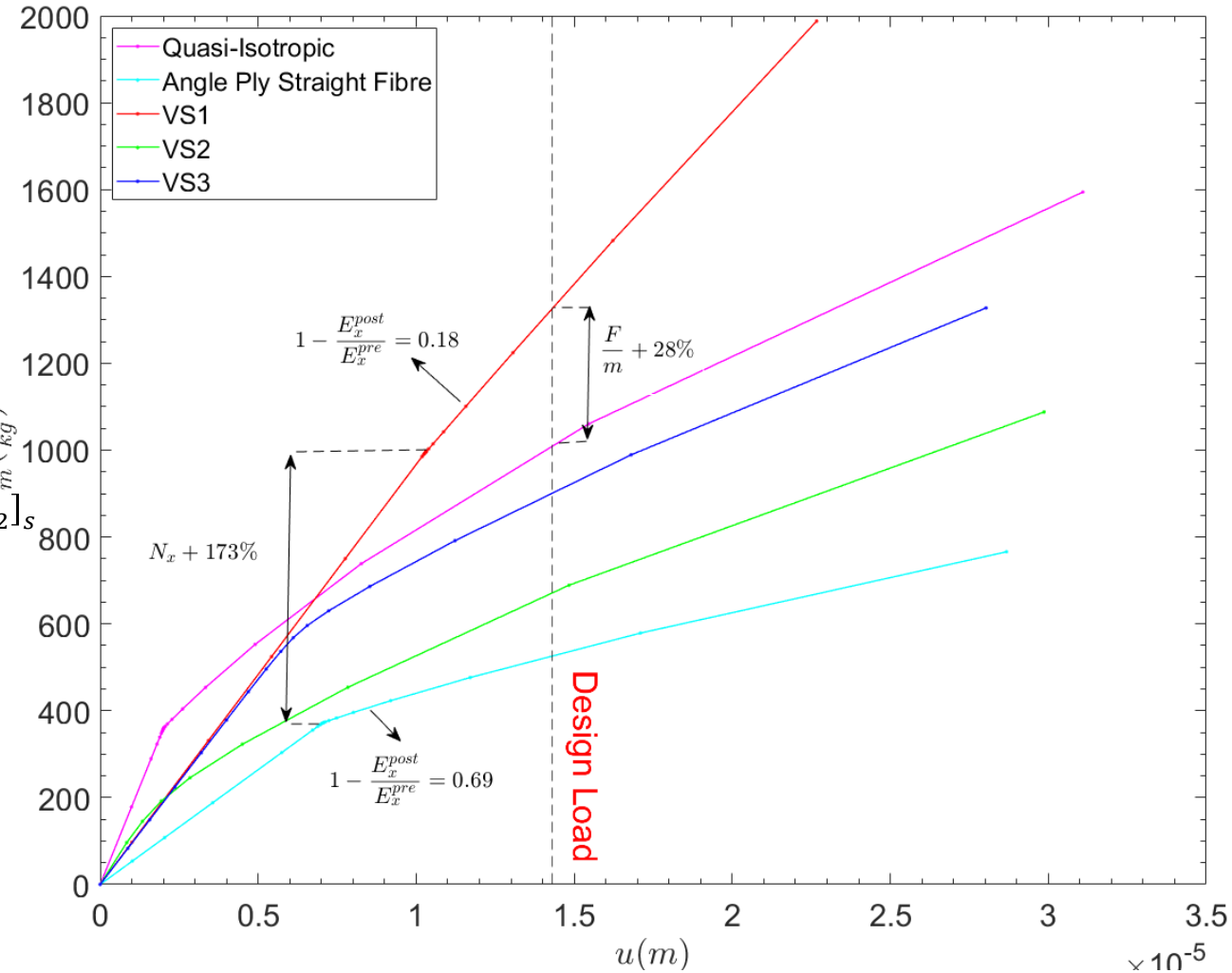
Structural Targets

Results: Design for Load-Carrying Capacity

- Considering only balanced and symmetric layups
- No ‘bucklephobic’ design constraints

- Tailoring conducted on;
  - **Constant stiffness (CS)**, angle ply laminate
    - $[\pm\theta_1/\pm\theta_2]_s$, $[t_0]_{4s}$
  - **Variable stiffness (VS)**, fibre-steered laminate
    - $[\pm\theta_1(x,y)/\pm\theta_2(x,y)]_s$, $[(t_0 \sec\theta(x,y))_2/(t_0 \sec\theta(x,y))_2]_s$

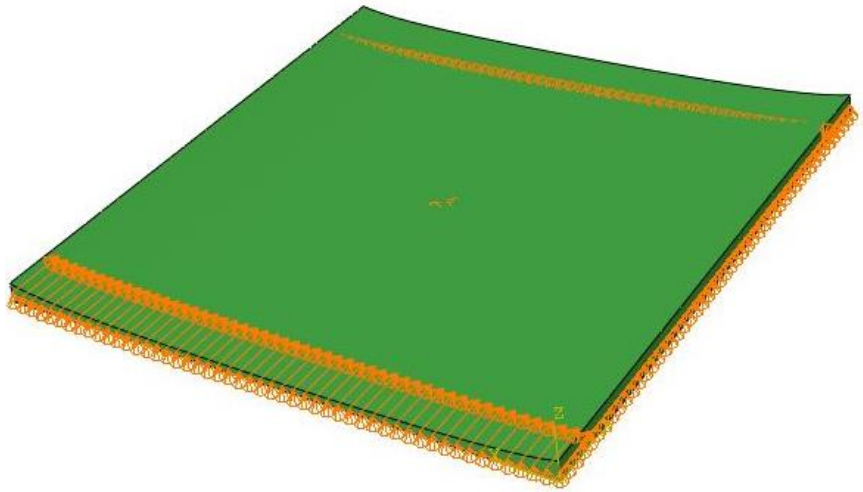
- Fibre-steered panels
  1. Increase and delay buckling load
  2. Improve postbuckling stability
  3. Increase mass-efficient load-carrying capacity



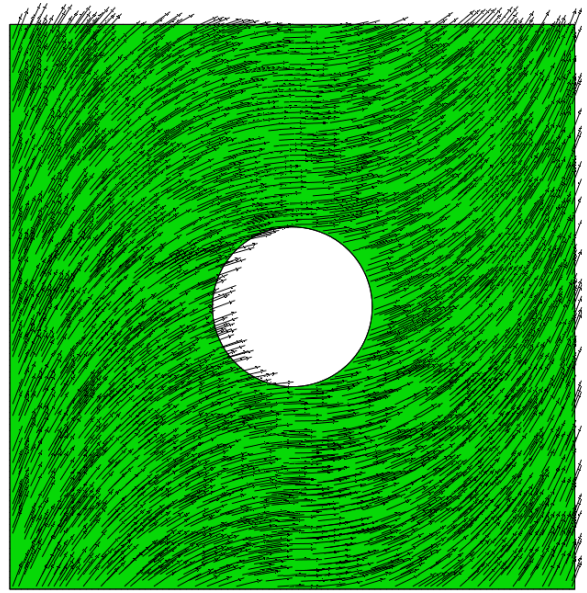
Conclusions & Future Work

- Significant scope for performance tailoring
- Increased design space allows for novel design
- Fibre-steered structures can achieve greater mass-specific performance

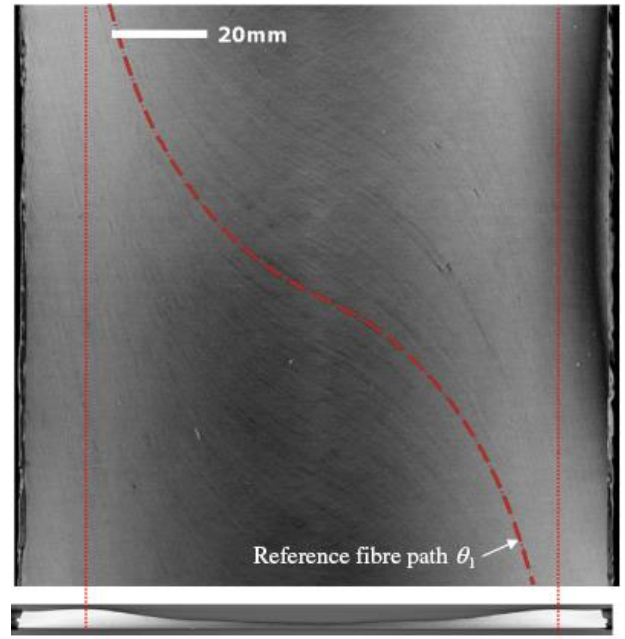
- Meta-heuristic optimsiation to identify true solution space minima
- Addition of geometric features (cutouts)



Numerically Discretised simply supported CTS Plate under compression



Holed Fibre-Steered Plate



Manufactured CTS Plate

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Questions?

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[1] R. Wanhill, Carbon Fibre Polymer Matrix Structural Composites, Springer, 2016

[2] B. C. Kim, K. Potter and P. M. Weaver, "Continuous tow shearing for manufacturing variable angle tow composites," Composites: Part A, vol. 43, pp. 1347-1356, 2012