QUB- Mechanical and Aerospace Engineering

PhD Project 2021-22

Uncertainty propagation across scales for composite laminates

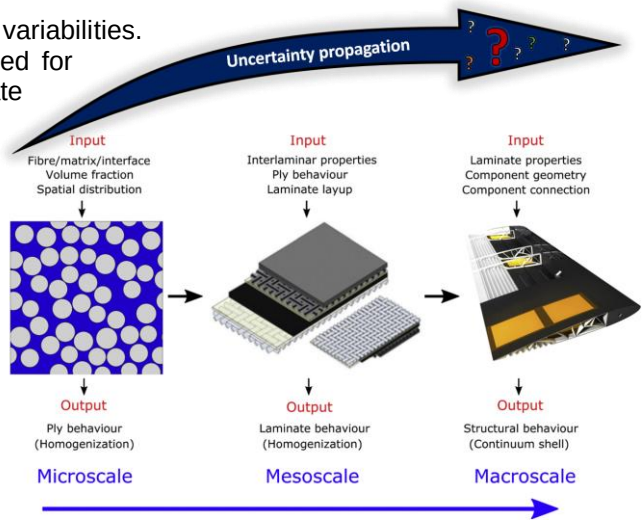
Project description:

Due to the multiphase and heterogeneous nature of carbon fiber-reinforced polymer (CFRP) laminates, the system properties can exhibit variability in nature, resulting in uncertainty on the response of the structure. Therefore, some variabilities need to be considered in the mechanical response of composite structures. Scatter in material properties influences the quality of the material, the product or the effect of a processing step. In composites, scatter is affected by differences in (i) fibre path, (ii) void content and distribution, and (iii) presence of microcracks. Natural material variability, manufacturing defects, and material parameters cause composites to possess variations in their mechanical response. With respect to material variability: fibre diameter & length & distribution within the polymer matrix, among other properties, are observed; regarding manufactured imperfections: variability in the fibre volume fraction, voids, fibre misalignment, thickness distribution, and interlaminar defects are normally expected to appear to a greater or lesser extent. Fracture/material parameters include elastic properties, strength limits, fracture toughness, and model parameters.

Uncertainties are classified as either aleatory (inherent randomness in the system) or epistemic (due to partial knowledge of the problem and parameters). Aleatory (random) refers to fibre and matrix characteristics, manufacturing variations, among others; whereas epistemic is associated with the type of the methods considered. These uncertainties are currently accounted for through a conservative approach to composite structural design. Incorporating uncertainties in the design of CFRP structures for aerospace vehicle design will lead to less conservative factors (without compromising safety) and a reduction of design cycle times through reduced experimental testing.

Probabilistic methods can be used to quantify these variabilities. Probability distribution functions (PDF) may be established for all uncertain parameters, giving the possibility to correlate several parameters. The outcome may be interpreted in a statistical sense, and the probability of each output quantity depends on the input probabilities and their correlations. It is vital that these inputs are somehow validated in order to allow a proper statistical interpretation, which is usually neglected, and assumptions are made on the input PDFs.

The Figure on the right side shows that different factors take place at each length scale in a composite structure. Therefore, it becomes essential to understand to quantify them within their scale and how they affect other scales, i.e. how they propagate across scales and what these uncertain events might entail.



Adapted from Tan W, Falzon BG, et al. Compos B Eng 2018;138:206-221.

Aims and Objectives:

This PhD project aims at overcoming current limitations with regards to quantify uncertainties related to material and manufacturing parameters and investigate how they affect and propagate across length scales. The considered scales are: micro, meso and macro.

It is aimed to develop a bottom-up stochastic multiscale model taking uncertainties into account using the finite element (FE) method. The utilization of metamodels is aimed to train the FE models towards developing computationally efficient frameworks.

The outcomes from the framework will allow understanding the failure and damage mechanisms of composite laminates under several loading scenarios.

Key skills required for the post:

Candidate should demonstrate knowledge/experience/skills in at least one of the following areas:

- Computational modelling
- Python scripting
- Mechanics of composites
- Finite element modelling (preferably Abaqus)
- Stochastic modelling
- Advanced statistics

Key transferable skills that will be developed during the PhD:

These will include an ability to effectively communicate research outcomes to academic peers and industry, independent analytical thinking and problem solving, time management, and leadership.

Lead supervisor:	Dr Humberto Almeida Jr Royal Academy of Engineering Research Fellow e-mail: humberto.almeida@qub.ac.uk
Other supervisors:	Prof Brian G. Falzon CEng FRAeS Professor of Composite Materials and Aerostructures Head of School, b.falzon@qub.ac.uk
Funding mechanism:	UK nationals only.
Application closing date:	31st July 2021
Guaranteed stipend	£15,285 tax free.

PhD students in the School may have the opportunity to apply to be demonstrators on undergraduate modules. Compensation for this can amount to in excess of £2,400 per year.

Queens University Belfast is a diverse and international institution which is strongly committed to equality and diversity, and to selection on merit. Currently women are under-represented in research positions in the School and accordingly applications from women are particularly welcome.