QUB - Mechanical and Aerospace Engineering
PhD Project Description

Development of finite element-based computational framework for assessing the structural performance of advanced composite structures

Theme:

- **Composite materials and structures**
- **Simulation technologies**

Project description:

Fibre-reinforced polymer (FRP) composites consisting of two-dimensional reinforcement are used in a variety of industrial applications such as aerospace, automotive, marine, rail, energy, civil structures, biomedical, and oil and gas. The mechanical properties of these composites can be tailored in the plane of the fibres but suffer from having very weak mechanical properties in the out-of-plane direction due to the lack of reinforcement in this direction. The 3D-textile/woven composites having fibres oriented in all three directions (Figure 1) and therefore possess improved out-of-plane mechanical properties including stiffness, strength, delamination resistance, and impact performance. On the other hand, insertion of through-the-thickness reinforcements and forces experienced by these composites during the manufacturing processes leading to damaged and misaligned fibres leading to reduce mechanical properties. In addition to static loading, composite structures are also susceptible to damage from impact loading, e.g. tool drop, flying debris impact and bird strikes. Even in barely visible impact damage, the strength of these composite structures reduces significantly.

On the macro-level, 3D-textile composites can be considered as homogeneous but on the micro-level, these are heterogeneous consisting of glass/carbon fibres within the polymer matrix. The micro-level failure mechanism including matrix plasticity and fibre-matrix decohesion ultimately lead to failure of the macro-level structure. Therefore, multi-scale modelling provides an accurate modelling framework to simulate the behaviour of FRP composites and determine their structural response.

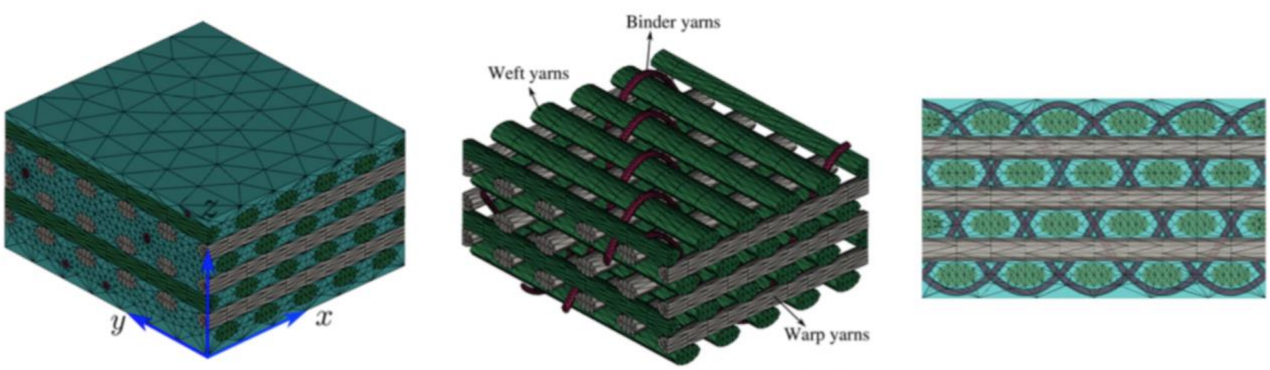

Figure 1: Idealised micro-structure of 3D-textile composites

Aims and Objectives:

This project aims to develop a novel computational framework and associated finite element software for the simulation of the structural performance of 3D-textile composites subjected to static and/or impact loading. For the accurate simulation of these composites, a realistic and detailed geometry modelling of their microstructure is very important. These realistic geometries will be obtained by subjected their idealised counterpart to the forces experienced by these composites during the manufacturing processes. The imposition of appropriate boundary condition on the micro-level structure is also very important for the calculation of accurate macro-level homogenised/effective mechanical properties, e.g. stiffnesses and Poisson's ratios. As compared to the displacement and traction boundary conditions, the periodic boundary condition is more accurate but requires periodic geometries and meshes for its numerical implementation. The forces experienced by the 3D-textile composites during the manufacturing processes result in microstructure with non-periodic geometries and meshes leading to numerical complications in the imposition of periodic boundary condition. Therefore, a robust finite element-based algorithm will be developed for the imposition of periodic boundary condition on the micro-level structure.

During their service lives, these composites are subjected to both static and impact loading. Therefore, as part of this project, a finite element-based computational framework will be developed for the simulation of the structural performance of 3D-textile composite structures. The computational framework will be developed for static loading and will be subsequently extended to impact loading. All the possible failure mechanism including elasto-plastic response of the matrix and fibre-matrix decohesion will be included. The response of the macro-level structure will be determined directly from the underlying micro-level structure. The multi-scale nature of the computational framework requires the solution of a micro-level finite element problem for each macro-level point of interest and is therefore computationally very demanding. Therefore, the developed computational framework will be optimised for the Queen's University high-performance computing cluster, Kelvin. The developed computational framework will be implemented in MoFEM (Mesh-Oriented Finite Element Method), an open-source finite element-based software library. The computational framework will be implemented in a generalised way and will be able to solve composite systems consisting of unidirectional and 2D-textile reinforcement.

This PhD project will be carried out within the Advanced Composites Research Group at Queen's University Belfast consisting of academics, PhDs and post-doctoral researchers.

Key skills required for the post:

- Knowledge of polymer-based fibre composites
- Knowledge of structural mechanics
- Basic experience of using finite element analysis and knowledge of its theoretical foundations
- Basic computer programming

Key transferable skills that will be developed during the PhD:

- Numerical modelling (finite element analysis)
- Composite materials and structures
- Project management, problem solving and communication skills

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Funding mechanism:	Yet to be secured
Application closing date:	
Guaranteed stipend:	Stipend for 20-21 is not yet confirmed. Base stipend for 19/20 is £15,009.
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.