# Manufacturing and Characterisation of Novel Near-Net-Shaped 3D Woven Composites for Maritime Application

# MANUFACTURING AND CHARACTERIZATION OF NOVEL NEAR-NET-SHAPED 3D WOVEN COMPOSITES FOR MARITIME APPLICATION

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## 1. Introduction

With the addition of through-thickness binders in 3D woven composites, delamination failure is initiated, allowing the composite to carry increasing loads well beyond first crack initiation [1]. Moreover, 3D weaving is gaining popularity in the industry over 2D weaving due to its capability to manufacture near-net-shape preforms reducing the manufacturing/machining cost [2]. However, the ability to produce complex integrated structures and excellent through-thickness strength and toughness of 3D woven composites is tempered by lower in-plane performance compared to 2D woven or unidirectional composites. This may be further exacerbated by process induced defects or variability. Although 3D woven composites show promising potential for various applications, their practical utilisation in structural components on a mass scale is limited by high initial equipment cost and the lack of a thorough understanding of the effect of weaving parameters in the textiles on the mechanical and impact performance.

Today, a complex construction geometry structure used in maritime industry consisting of node connections and area components is commonly achieved by a laminate structure of individual layers prior to consolidation. These layers are not interconnected instead only laminated. When subjected to loading, the layers tend to split resulting delamination as the main failure more. Along with delamination, manufacturing of laminated composites is laborious, time consuming and results in waste from ply cutting. To address this problem, 3D weaving gives the flexibility to produce near net-shaped profiles, including solid beams, shell beams, modular joints, pocket structures, 3D hollow fabrics. Different architectures of variable thickness can be woven into other parts of the near net shaped preform. For instance, in a T shaped architecture, the main body can have an architecture of double the thickness compared to its flanges. Thickness variation functionally graded preforms can be developed using 3D weaving technology.

A substantial amount of work has been performed to characterize three fundamentally different architectures of 3D woven composites (layer-to-layer, angle interlock, and orthogonal) for their failure mechanisms and mechanical performance [2]. However, limited literature exists around manufacturing and characterization of near net shaped 3D woven composites in industrial application. The purpose of this paper is to widen knowledge about the manufacturing and characterization of near net shaped 3D woven composites designed especially for maritime industry.

## 2. Experimental

A near net shaped composite foil for maritime application was manufactured using 3D woven angle interlock architecture preform. This near net shaped 3D woven preform consisted of four sections (front section- D1, Rib 1- D2, Rib 2- D3 and rear section- D4) as shown in Figure 1. To weave each section on the DATAWEAVE controlled jacquard loom at Ulster University, different architectures and textile design plans were made on Scotweave CAD software as shown in Figure 2 and Figure 3. Toray T700S-50C 12K carbon fibres in the warp and T700S-50C 24K carbon fibres in the weft were used in the manufacture the entire foil section with two ribs. 3D woven near net shaped foil preforms was consolidated using the Gurit Prime™ 37LV epoxy resin system via Vacuum assisted Resin Transfer Moulding (VARTM). The resin system was prepared as a two-part epoxy resin system with a resin to hardener ratio 100:29 by weight. After injection, the part was cured at 50°C for 16 hours. To make a comparison, 2D woven composite foil was also manufactured using 8 layers of T700S-50C-12k 2D woven preforms in laid up in 0/90 orientation.

The microstructure of critical sections of the foil like the T shapes and the joint region were observed through micrographs and micro computed tomography (CT) scan. This analysis identified key defects associates with fibre misalignment, voids and resin pockets. To study the tensile properties of the critical sections on the foil, tensile tests were performed in accordance with ASTM 3039 using Zwick universal testing machine on the T sections. An extensometer was used to record accurate strain up to 0.8%.

## 3. Results

The results of the tensile tests revealed that the T sections of 3D woven composites were stronger than the 2D laminate specimens. The extent of delamination was higher in 2D woven composites compared to 3D woven composites. The presence of z-binders in 3D woven composites arrested and delayed the crack propagation resulting improved properties in 3D woven composites.

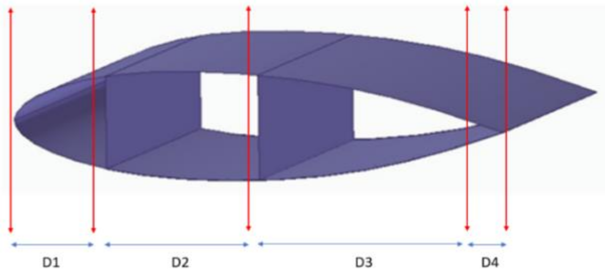


Fig. 1: Diagram representing the foil section used for maritime application made up of part parts of 3D woven preform (D1, D2, D3 and D4)

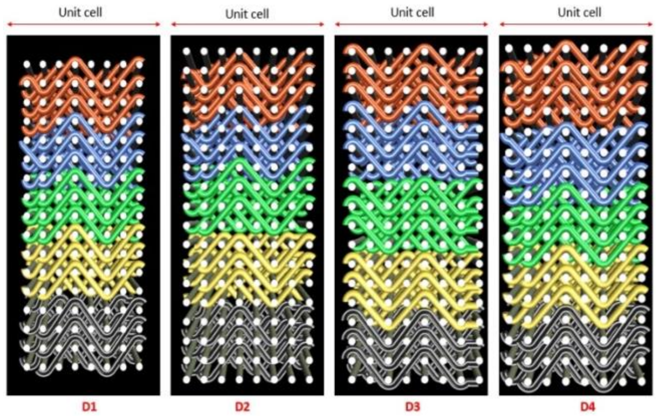


Figure 2: Architecture of unit cell of D1, D2, D3 and D4 unit cell for entire foil

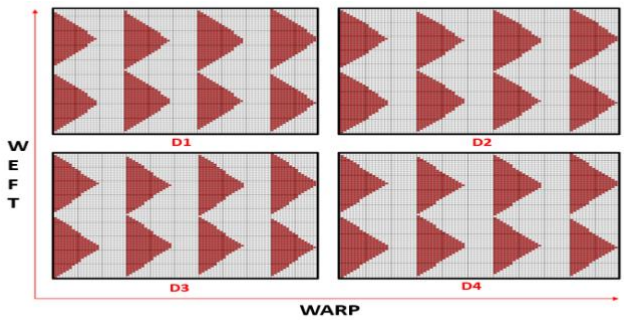


Figure 3: D1, D2, D3 and D4 textile design plan for the foil

## 4. References

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