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

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Artemis Project

UKRI Strength in Places Project

Project Partners

- £33M research programme (2020-2024).
- A Belfast Maritime consortium led by Artemis Technologies.
- Integrated, multidisciplinary and highly innovative research and skills development programme, to develop a zero emissions ferries in the city that will revolutionize the future of maritime transport.

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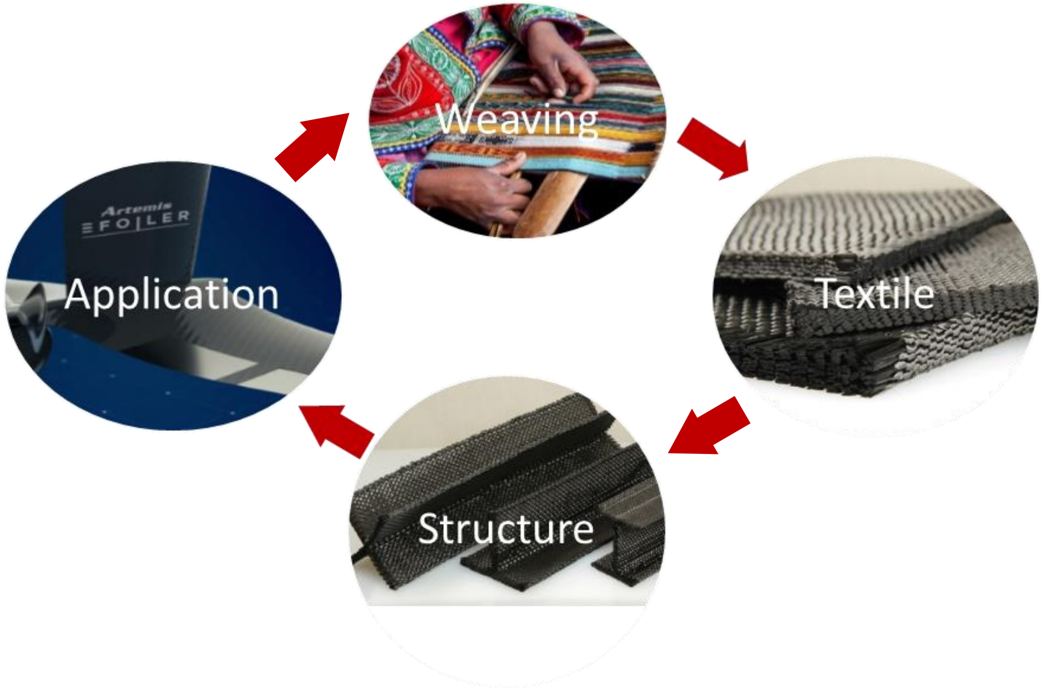
Motivation & Objectives



Research Gap:

- Limited knowledge about manufacturing of **near-net-shaped bespoke 3D woven** preforms for marine structures.
- **Lack of experimental data, experience and tools** to predict the properties of 3D woven composites**.**
- **Limitations** on the 3D weaving jacquard loom.
- **Performance** of 3D woven composites for maritime application

Objectives:

- To design **novel near net shaped 3D fibre architectures for hydrofoil structure** that provides enhanced conformability along with improved performance.
- Influence of architecture on **sea water ingress** and **mechanical performance degradation**.
- **Comparison between 2D and 3D woven composites** for mechanical properties degradation under sea water conditions.

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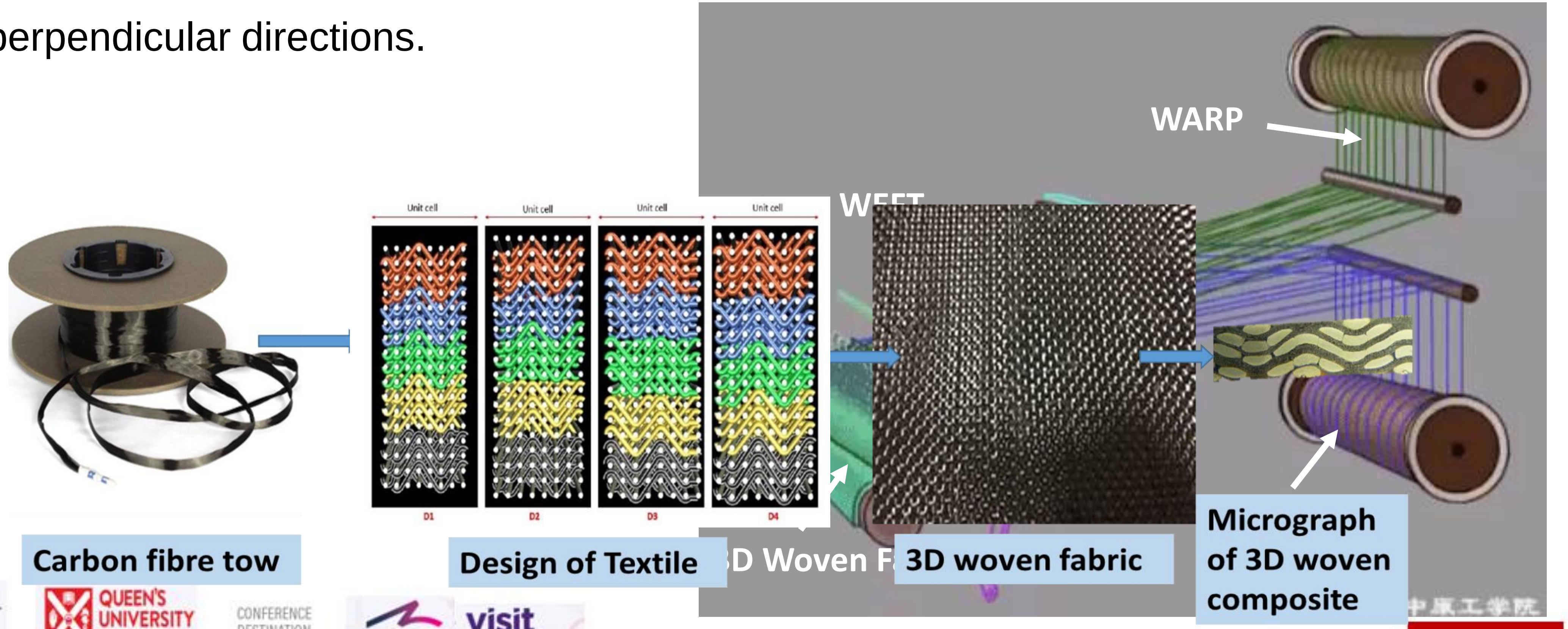
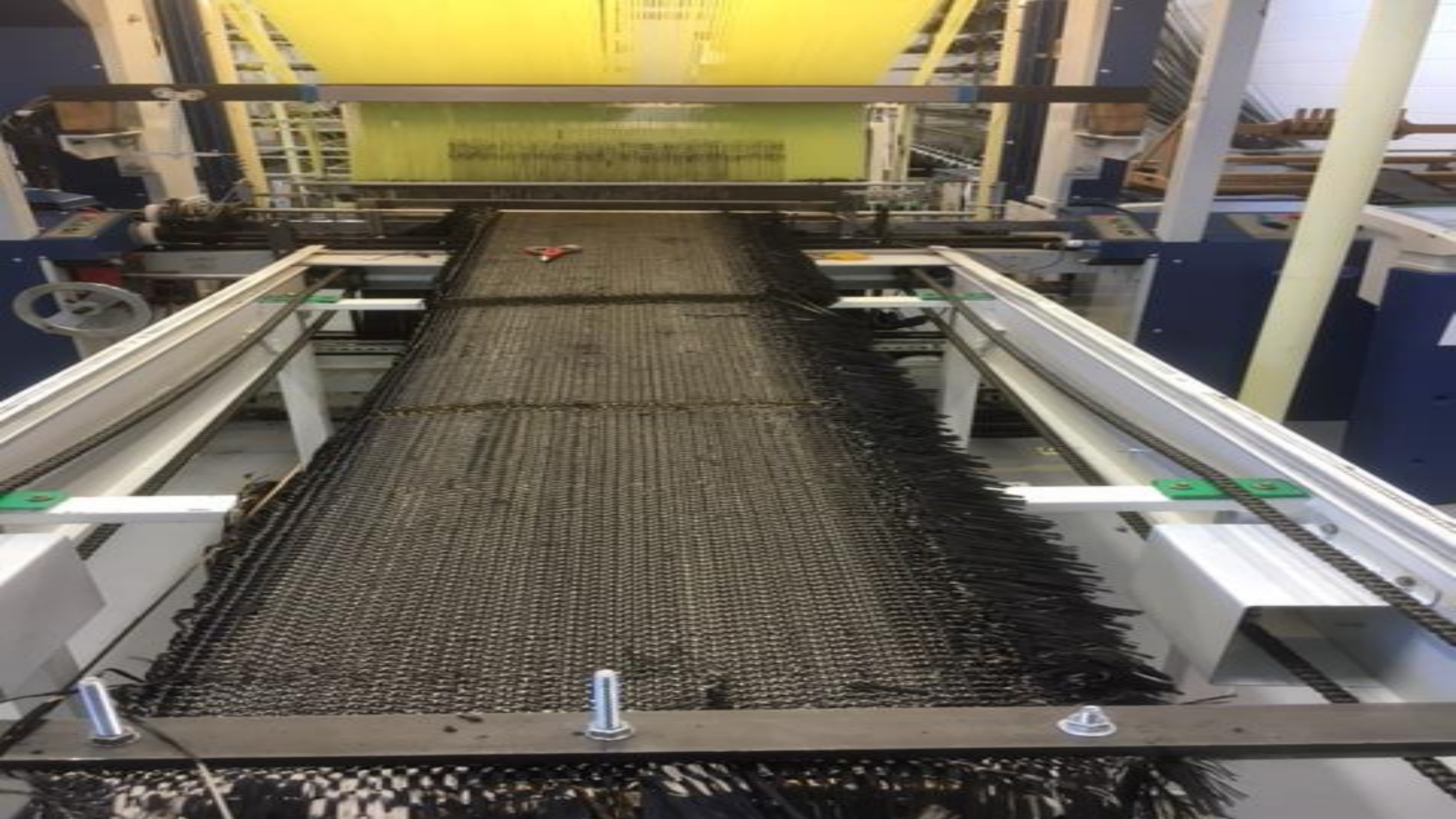
Manufacturing of 3D woven composites

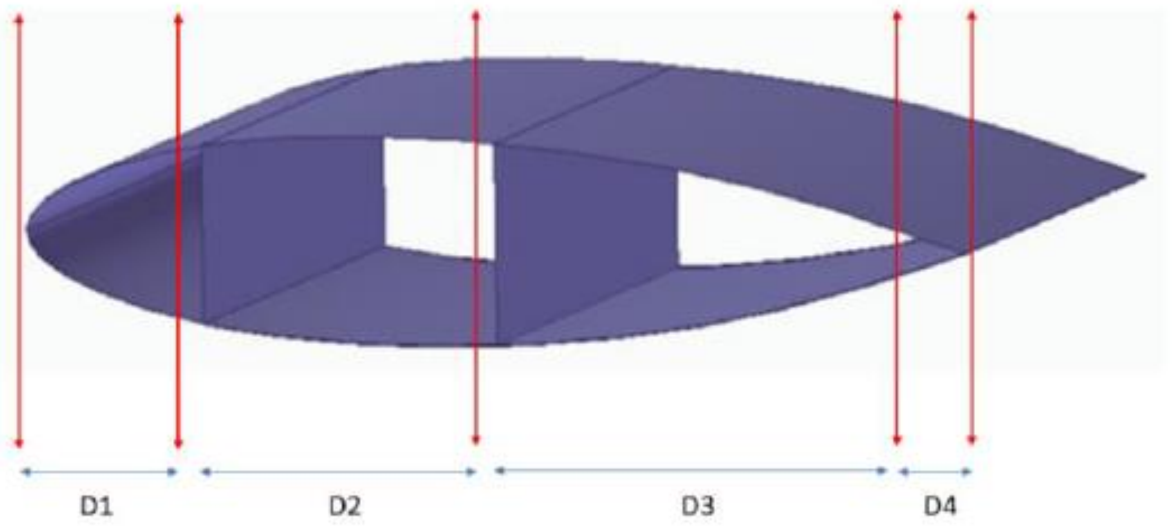
3D weaving is defined as the interlacement of warp weft and binder yarns in three mutually perpendicular directions.

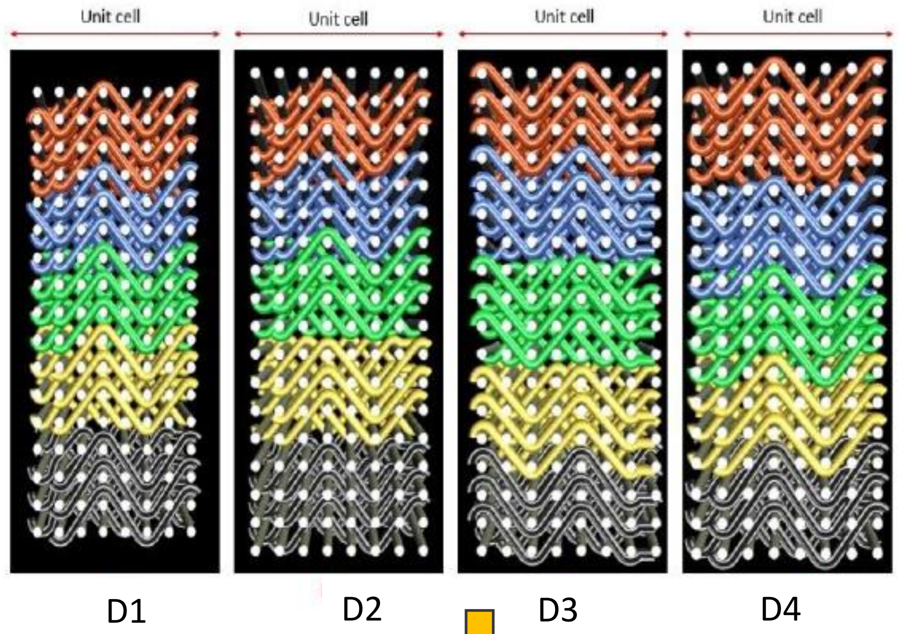


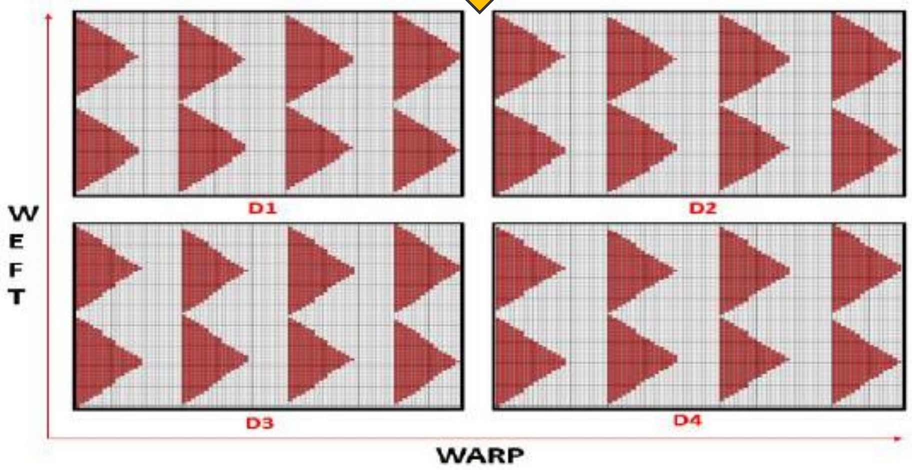


Hydrofoil- Textile Design Plan 1

Textile Design plan 1: Dividing the hydrofoil structure into 4 units with each unit having a unique textile design plan.

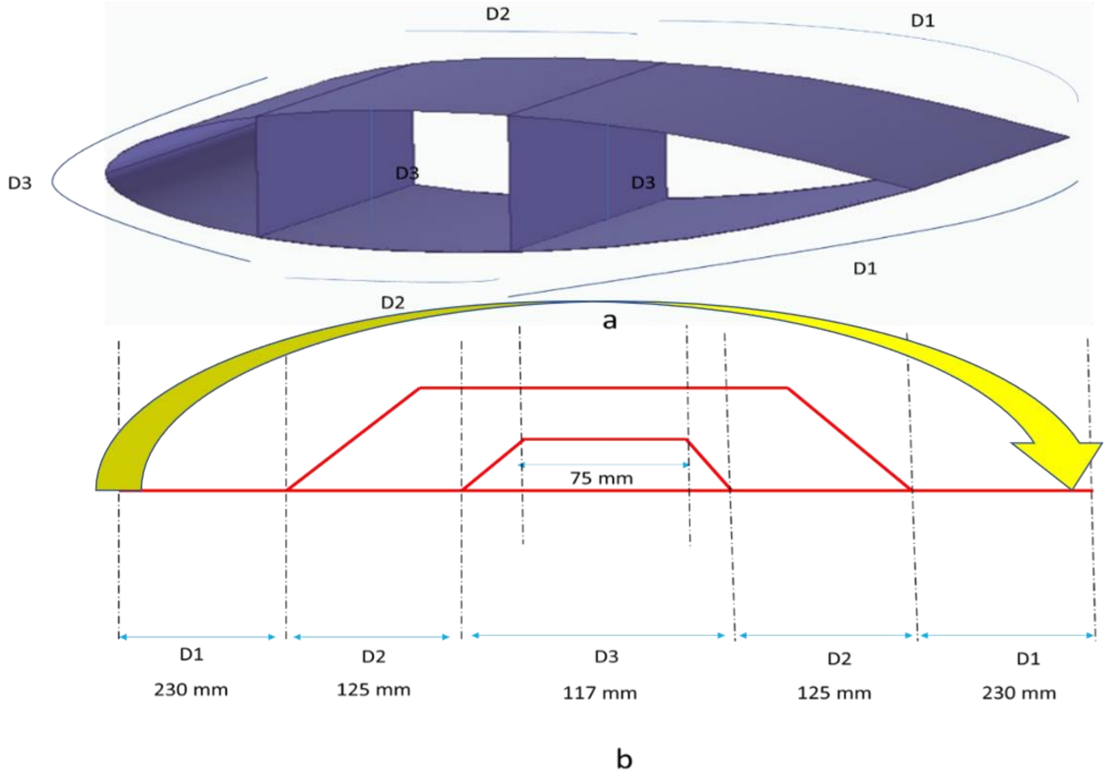


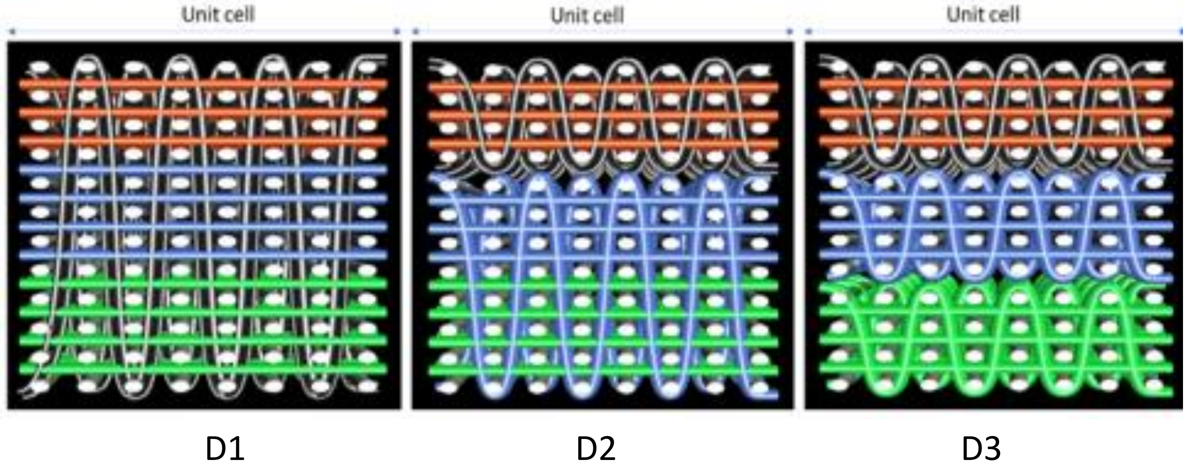


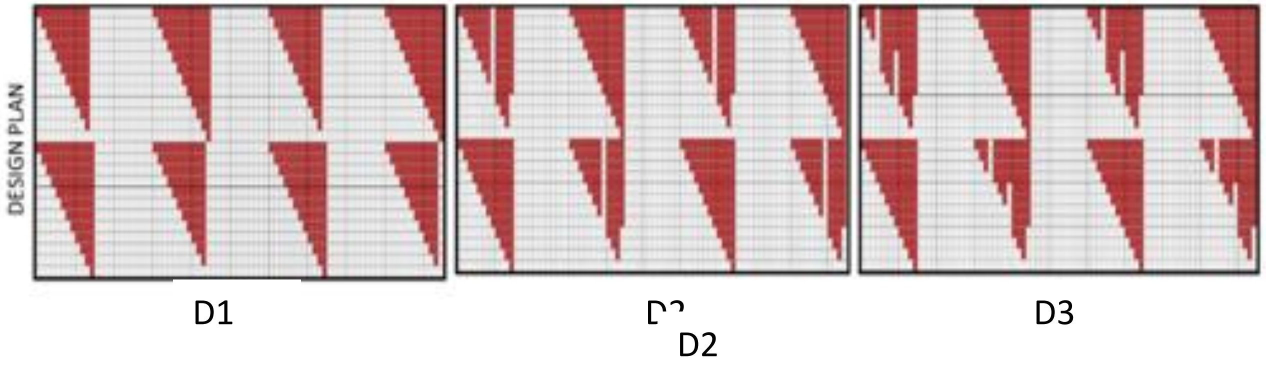


Hydrofoil- Textile Design Plan 2

Textile Design plan 2: Dividing the hydrofoil structure into 3 units and folding the preform over with each unit having a unique textile design plan.







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Manufactured Near-net-shaped preforms

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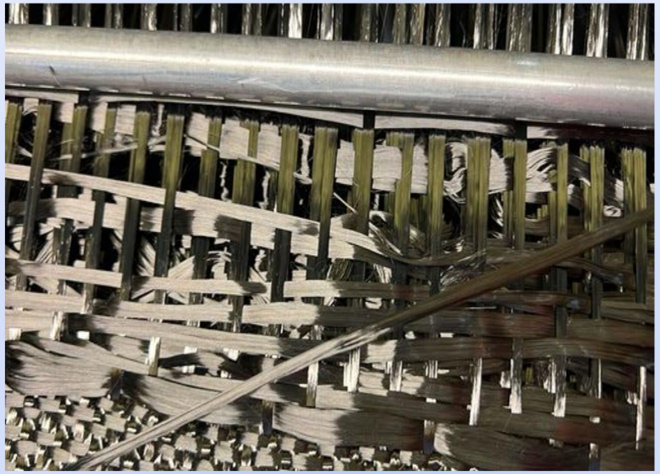
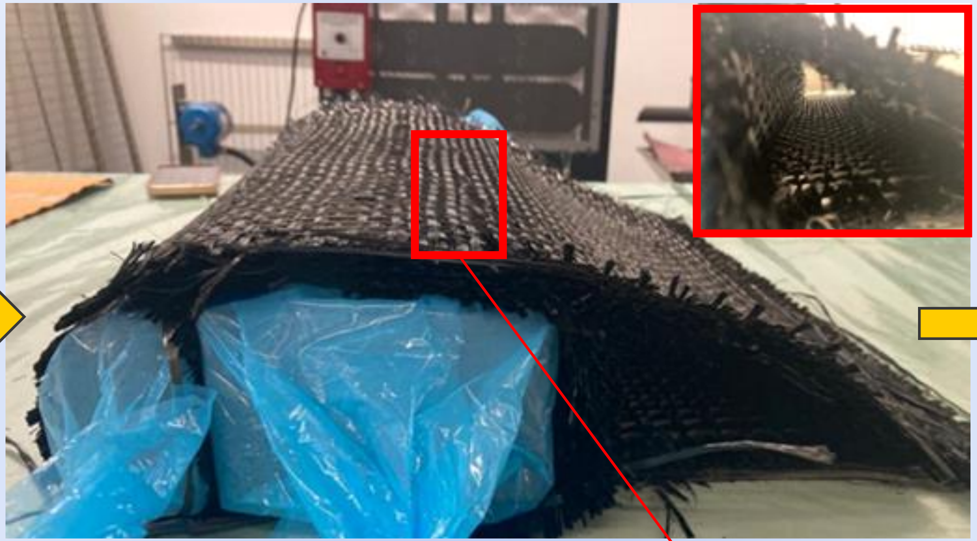
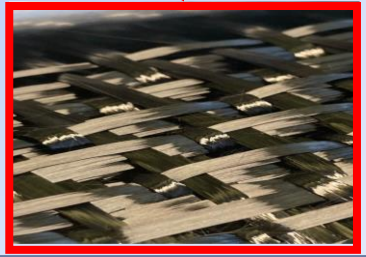


Manufactured using Textile Design Plan 1

- Top layer loose and bottom tight
- Significant yarn distortion





Manufactured using Textile Design Plan 2

- Uniform architecture through the thickness

Textile Design Plan 2- Wet lay-up

Characterisation of 3D woven architecture in Hydrofoil structure under sea water conditions

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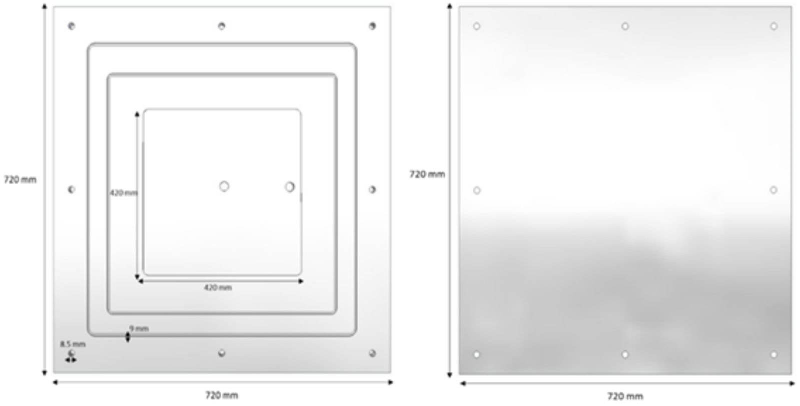
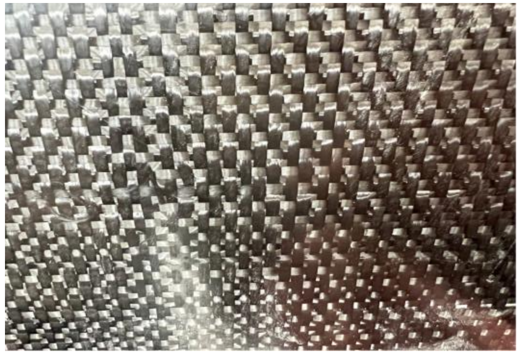
- Layer-to-Layer architecture used in near-net-shaped 3D woven hydrofoil preform.
- Influence of sea water on 3D woven composites under sea water has been studied. Also, a comparison of properties with 2D woven composite with similar fibre volume fraction has been made



Flat plate design RTM tool



3D woven composite

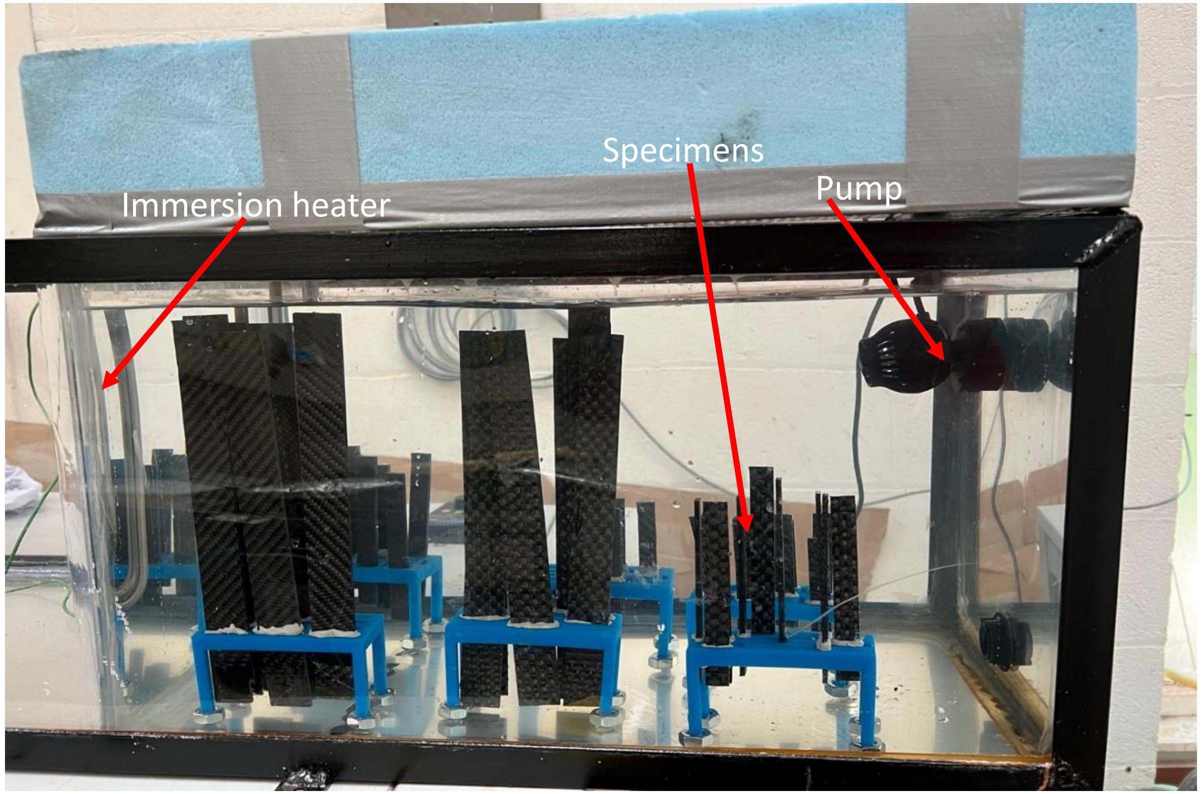
Layer-to-layer architecture
Resin system: Gurit Prime 37
Fibre Volume Fraction: 42.4%
Composite thickness: 3mm

2D woven composite

Plain Weave: 0/90
Resin system: Gurit Prime 37
Fibre Volume Fraction: 43.1%
Composite thickness: 3.1mm

Fibre property	3D woven- T700S-50C	2D woven- T700S-50C
Yarn filament size	12K	12K
Fibre Density (g/cm^3)	1.8	1.8
Fibre Strength (MPa)	4900	4900
Fibre Modulus (GPa)	2.3	2.3

Sea Water Ageing Setup



<u>Sea water ageing studies</u>

Artificial sea water (ASTM D1141-98)

Accelerated ageing- Temp 50°C

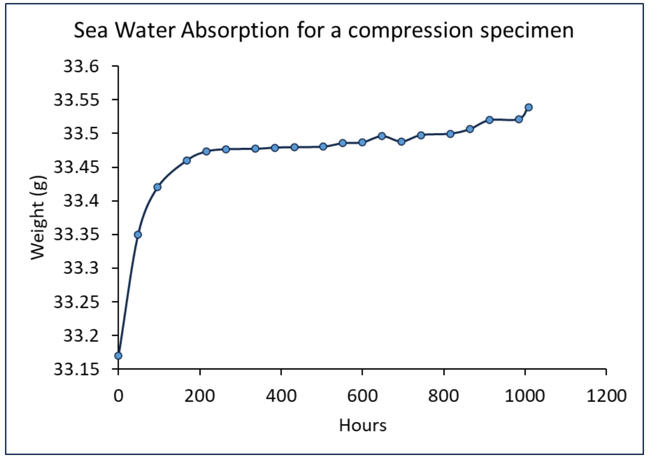
Wave simulating pump

Duration: 1200 hours (50 days)

Sea Water Testing Results: Comparison of 2D and 3D woven composites

	Warp		Weft	
	2D woven composite	3D woven composite	2D woven composite	3D woven composite
Tensile specimens	4.34	2.69	0.83	1.78
Flexure Specimens	2.25	2.08	4.82	1.94

% Sea water absorption over 1200 hours (50 days)



Typical graph of sea water absorption over 50 days (fickian diffusion)

600 hours- 2D woven composite flexure specimen

600 hours- 3D woven composite flexure specimen

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Sea Water Testing Results: Comparison of 2D and 3D woven composites

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$$\Delta M(t) = \frac{m_t - m_o}{m_o} \times 100$$

ΔM(t): moisture uptake,
M_o and M_t are mass of the specimen before and during aging

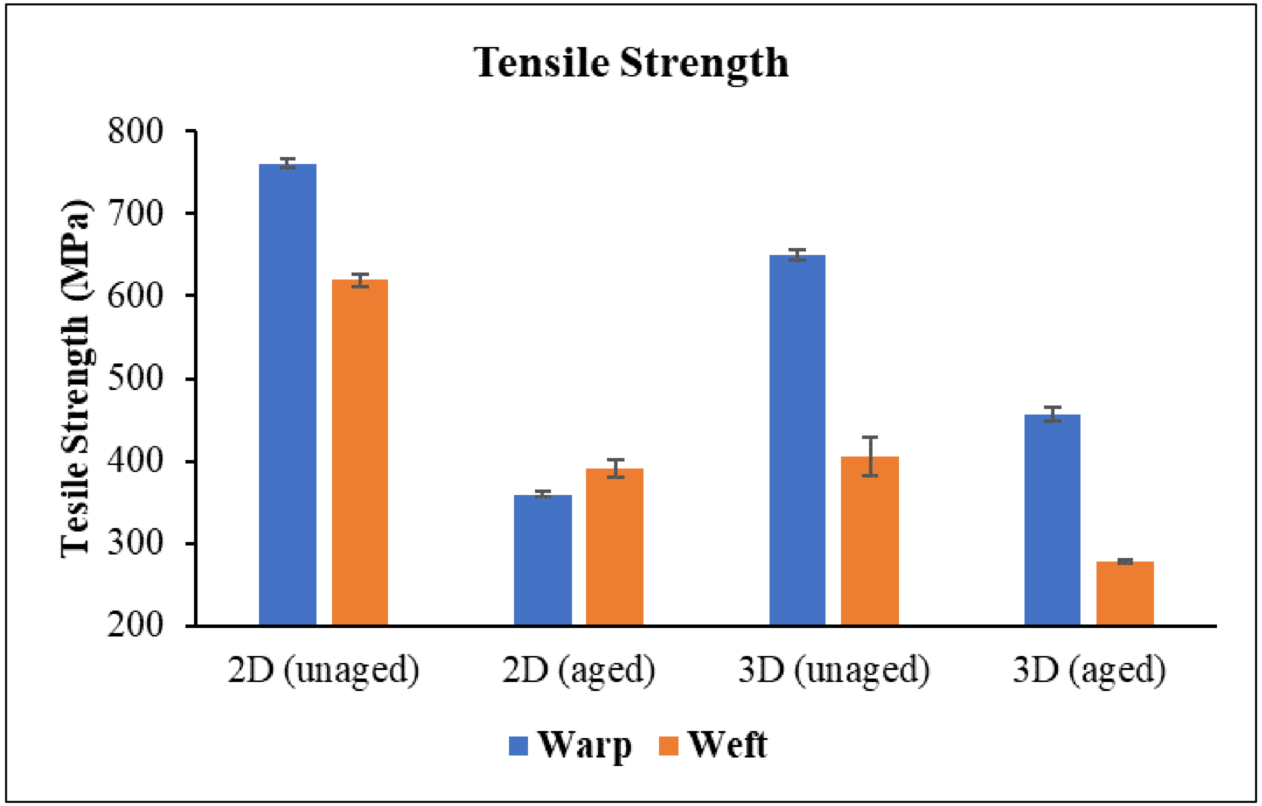
$$D = \pi\left(\frac{kh}{4M_m}\right)^2$$

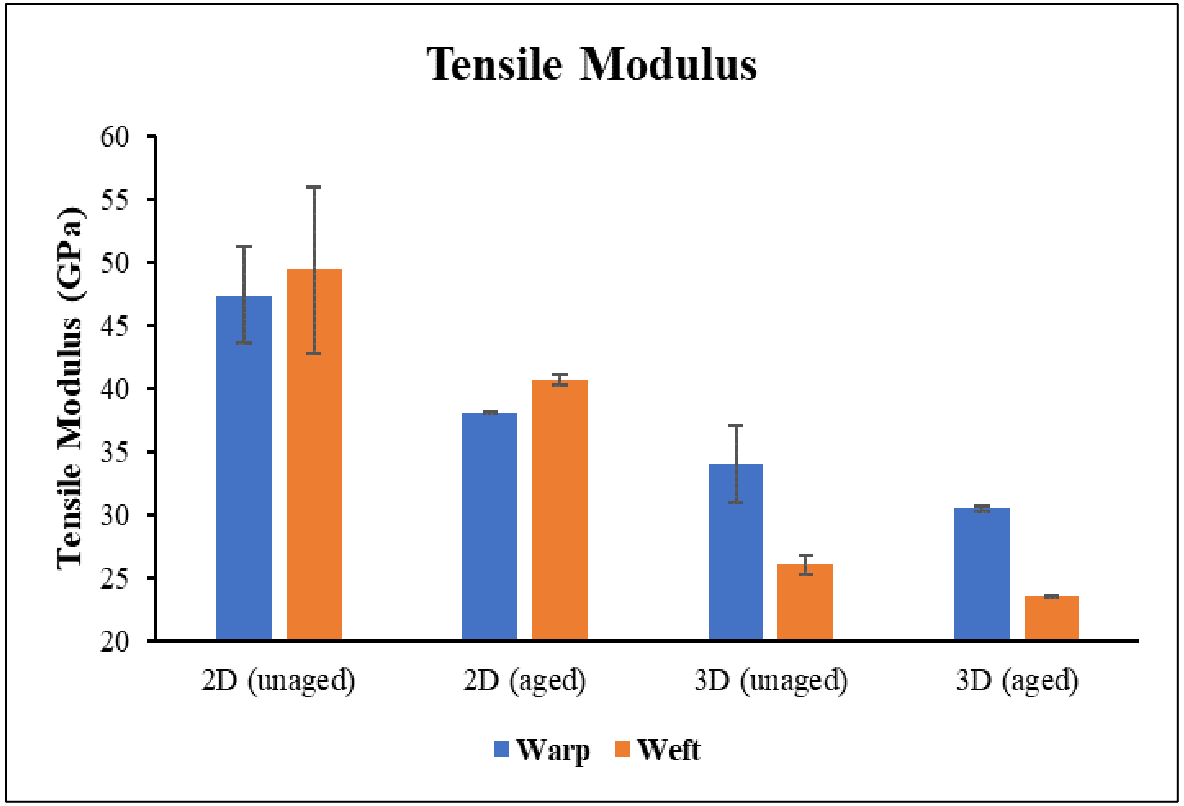
D: Diffusion coefficient
k: initial slope of a plot of M(t) versus t^1/2,
M_m: maximum weight gain
H: thickness of the composites.

Samples (10^(-3))	Tension- Diffusion coefficient		Compression- Diffusion coefficient		Flexure- Diffusion coefficient	
	Warp	Weft	Warp	Weft	Warp	Weft
2D woven composite	3.96	4.79	7.82	9.86	8.21	6.46
3D woven composite	2.86	1.92	3.60	2.24	3.02	1.67

Comparison of Diffusion Coefficients for 2D and 3D woven composites

Sea Water Testing Results: Comparison of 2D and 3D woven composites





Sea Water Testing Results: Comparison of 2D and 3D woven composites

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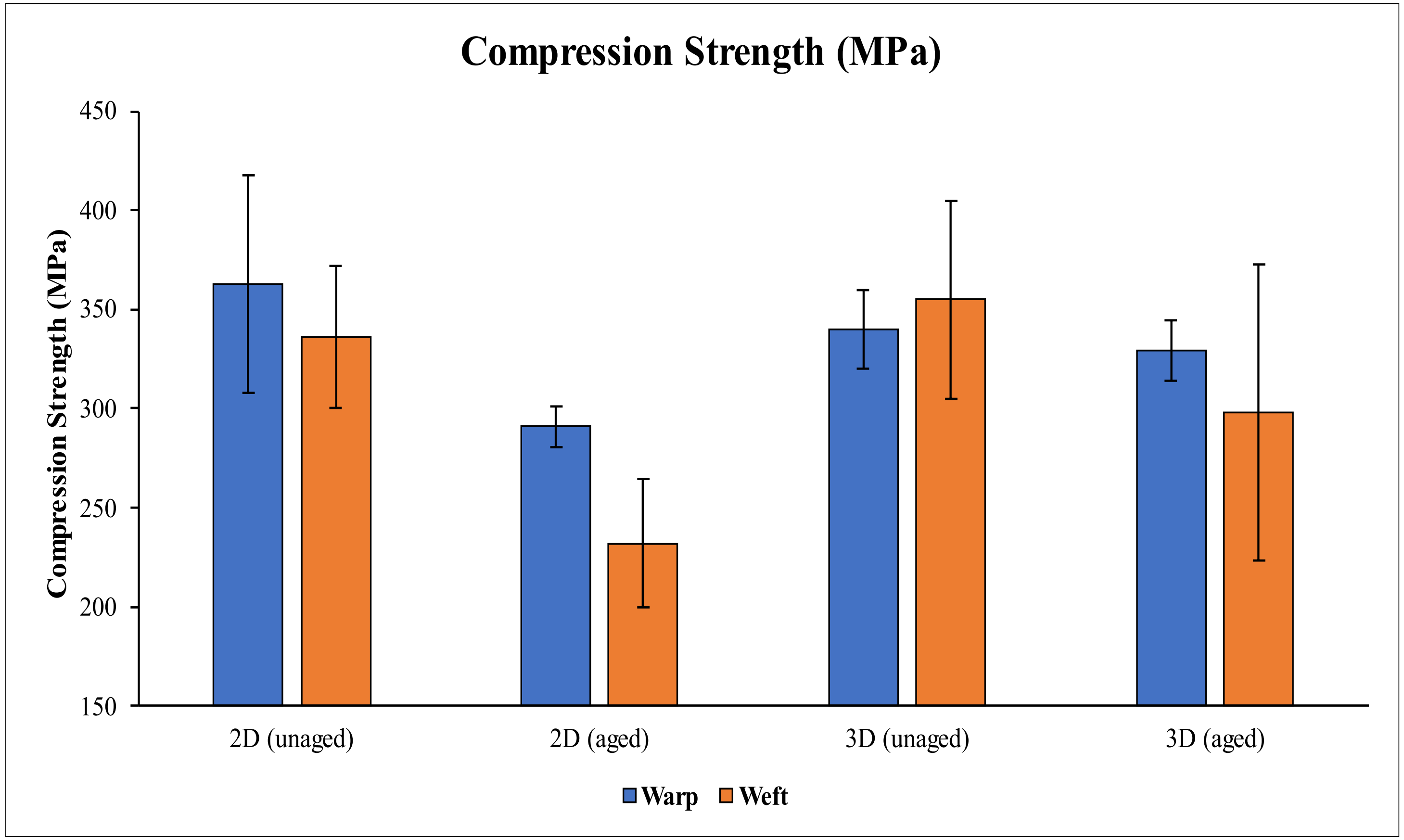

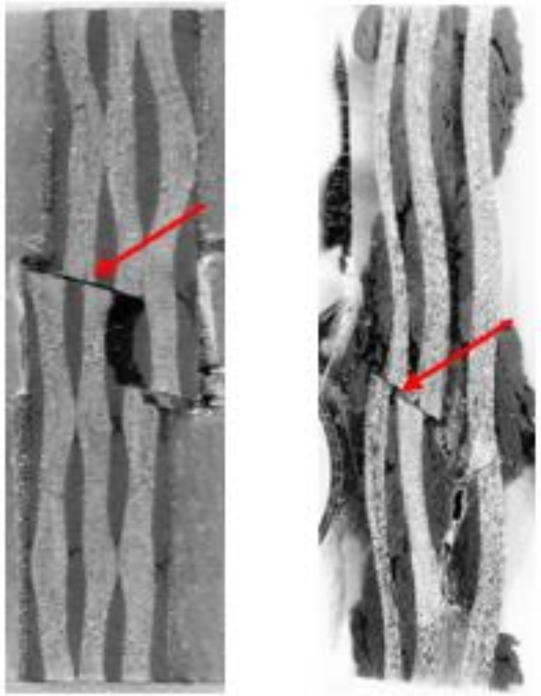

Unaged 3D woven & aged 3D woven specimens

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Conclusion

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- The near-net-shaped 3D woven hydrofoil preforms were manufactured without any changes to the loom set-up (textile design plan changes). This resulted in significant and cost and time reduction.

- Net-net-shaped preforms manufactured using textile design plan 1 resulted in significant yarn distortion compared to more uniform preform developed using textile design plan 2.

- 2D woven composites absorbed significant higher sea water compared to 3D woven composites when tested for 50 days at 50ºC.

- Although the in-plane mechanical performance of 2D woven composites was higher than 3D woven composites, the percentage degradation of these properties tested after immersed in sea water for 50 days were significantly higher for 2D compared to 3D woven composites.

Thank You

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