Experimental Investigation on the effect of thickness on the flexural properties of glass/vinyl-ester composite laminates for marine applications

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Irish Composites Centre

FIBRESHIP
INTEGRAL COMPOSITE SHIP

Bernal Institute

MECHCOMP 5th International Conference on Mechanics of Composites, Lisboa, 1 - 4 July 2019

University of Limerick
Ollscoil Luimnigh

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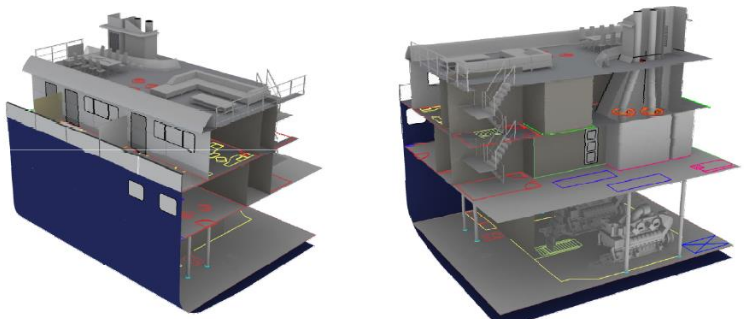

Ship Block Demonstrator

Background

- Composites dominate construction of small-to-medium length vessels (< 50 m)
- Restriction on use of composites on ships longer than 50 m !
- Main Reason: Lack of **design guidelines** from certification bodies
- Main issues: Safety - particularly **Fire**
- The trend in aviation (e.g. B787, A350) demonstrates that adoption of composite technology in primary and secondary structures is feasible

Courtesy of Tuco Marine (FIBRESHIP partner) – ProZero range of offshore/patrol/service FRP vessels (8-18 m)

PROMARINE, OUEST composites SEMI RIGID Boat (JEC 2019)

Challenge

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- Enhance acceptance of composites in primary structures of ships > 50 m
- Recommend relevant changes in rules and regulations to the responsible bodies
- Create a niche market opportunity for the manufacture of large marine vessels in the EU

Light Commercial Vessels

Representative Container Vessel

Passengers transportation & Leisure

Representative ROPAX

Special Services

Representative Fishing Research Vessel

Response: FIBRESHIP

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- **Engineering, production and life-cycle management for the complete construction of large-length FIBRE-based SHIPs**

- Innovation Action
- Total budget: 11.0M€;
  (EU contribution: 8.7M€)
- Coordinator: TSI SL, Spain
- Duration: 36 months from June 2017

CATEGORY I
Light Commercial Vessels

Representative
Container Vessel

- RoRo vessel
- Car Carrier
- Multi-purpose
- Freezer Vessel
- LNG
- Wood Transportation
- .....

COMPASS
Lloyd's Register
danaos

CATEGORY II
Passengers transportation & Leisure

Representative
ROPAX

- Ferries
- Passenger vessel
- Megayacht
- .....

SOERMAR S.A.
RINA
ANEK LINES
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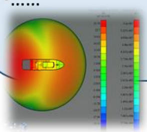
CATEGORY III
Special Services

Representative
Fishing Research Vessel

- Fishing vessel
- Seismic Vessel
- Supply vessel
- Rescue vessel
- ......

Tsi
BUREAU VERITAS



Partners

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- 18 partners, 11 countries
- European shipyards: 3
- Naval architect/design/engineering companies: 4
- Ship owners & operators: 4
- R&D organisations: 4
- Classification/certification bodies: 3

ANEK LINES www.anek.gr
TUCO MARINE GROUP
BUREAU VERITAS 1828
Tsi.
iXblue DIVISION H2X
CIMNE
TWI
FOINIKAS SHIPPING COMPANY
NAVROM SHIPYARD
FUNDACIÓN soermar
VTT
Ateknea Solutions
danaos
Lloyd's Register
COMPASS www.compassis.com
RINA SERVICES 1861 classification, certification, inspection & testing

Technical Impact

- Feasibility of the concept of a composite large-length ship
- Reduce fuel consumption by 10-15%
- Lower greenhouse gas emissions
- Improve ship stability and safety
- Underwater noise reduction
- Reduce maintenance and life cycle costs by 30%
- Corrosion-free

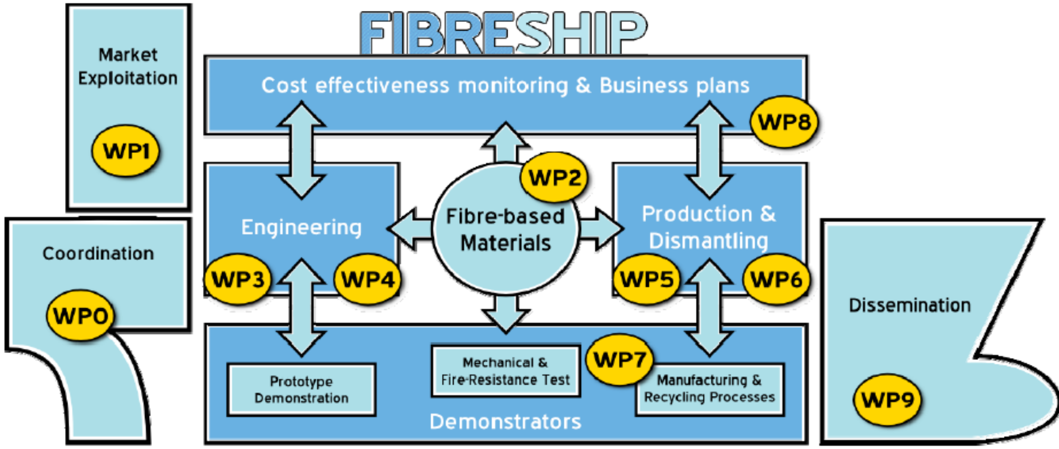
Safehaven marine 11-18 m

Swedish Navy Visby > 70 m

Our role in FIBRESHIP

Involved in 4 work packages:

- Materials (WP 2)
- Production (WP 5)
- Large-scale Validation (WP 7)
- Dissemination & Exploitation (WP 9)



Work Packages

Materials (WP 2)

FIBRESHIP INTEGRAL COMPOSITE SHIP

Which resins and reinforcements are viable solutions for large marine vessels ?

considering….

- *fire retardancy*
- *processability*
- *economics*
- *recycling*
- *mechanical properties*
- *environmental resistance..*

*Demonstrator under construction at iXblue, La Ciotat, France showing **laminate** and **sandwich** construction*

Materials (WP 2)

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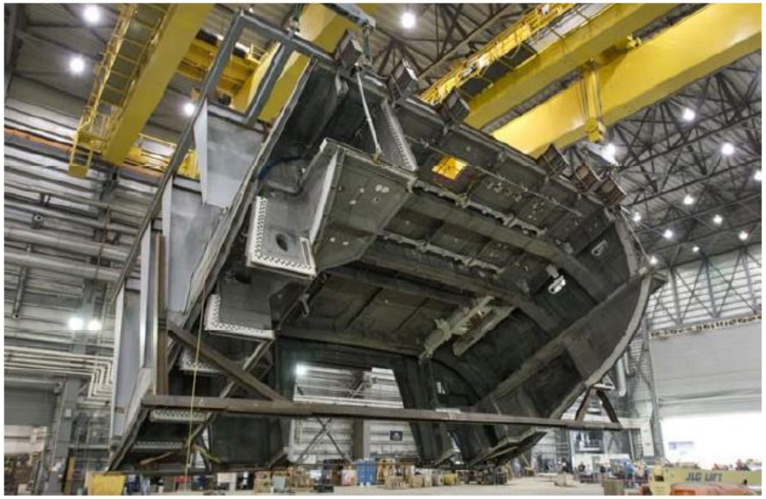
*Which **manufacturing processes** are most suitable for the manufacture of large marine vessels ?*

considering….

- *scale involved*
- *shipyard capabilities*
- *investment required*
- *future market*
- *skilled workforce available*
- *production rate*
- *need to automate..*



Composite ship block < 50 m long

Materials (WP 2)

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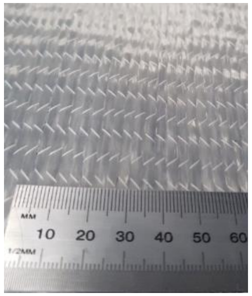
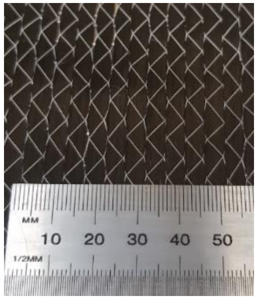
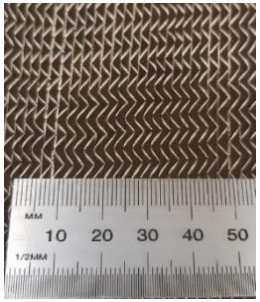
- **Liquid resin infusion** identified as the most suitable manufacturing technique…. familiar to ship yards, scalable, cost effective, flexible, closed mould infusion process
- Matrix of **infusible resin systems** was drawn up (x7 systems with a range of different chemistries)
- Thin laminates manufactured in the laboratory using a range of non-crimp fabric reinforcements
- Mechanical testing performed on samples extracted from thin laminates to obtain properties







Research Question!

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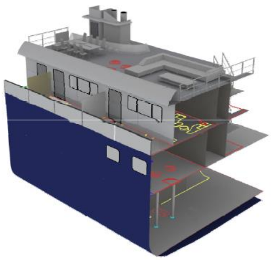
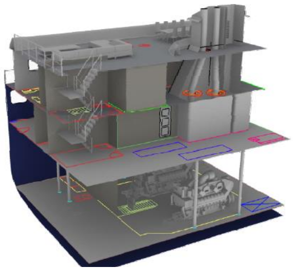
What about thick laminates manufactured at the ship yards ?

How do the mechanical properties compare with thin laminates manufactured in the lab ?





iXblue
DIVISION H2X

Study Overview

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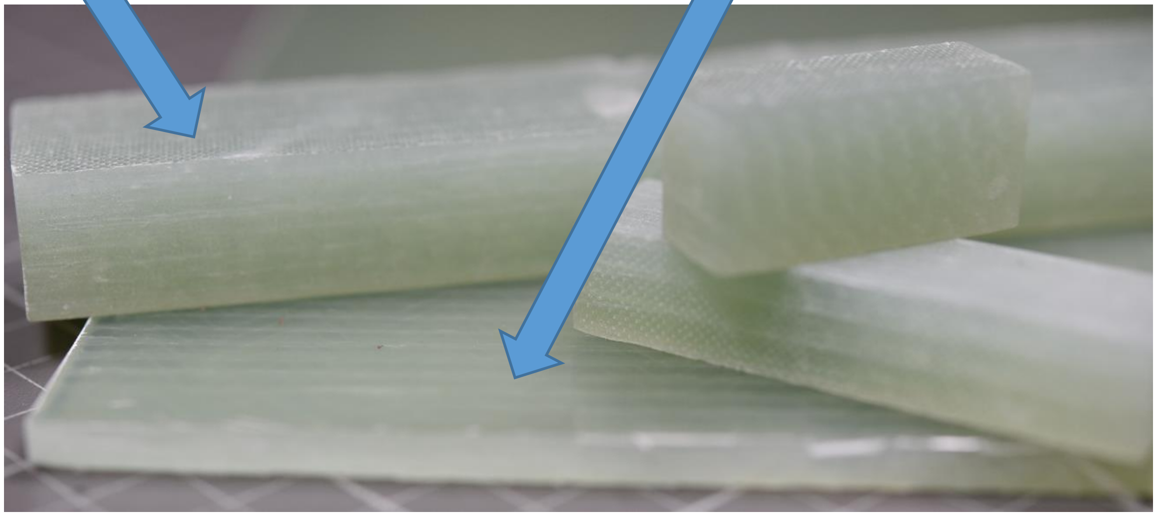
Manufactured at Shipyards

Manufactured at UL



- **Thin** laminate (~3.5 mm) manufactured at the **University of Limerick**
- **Thick** Laminate (~ 16 mm) manufactured at **ship yard**
- **All mechanical testing performed** at the University of Limerick

Test Matrix

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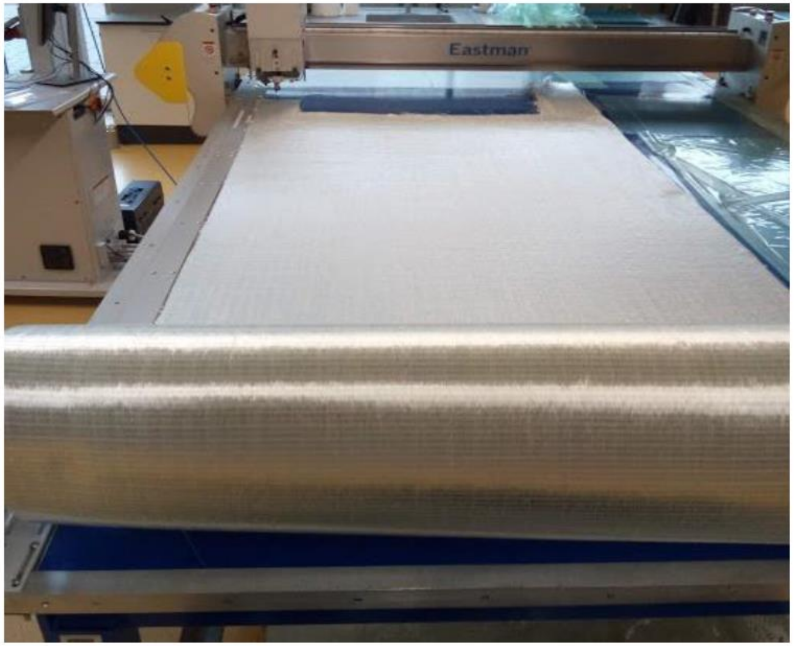
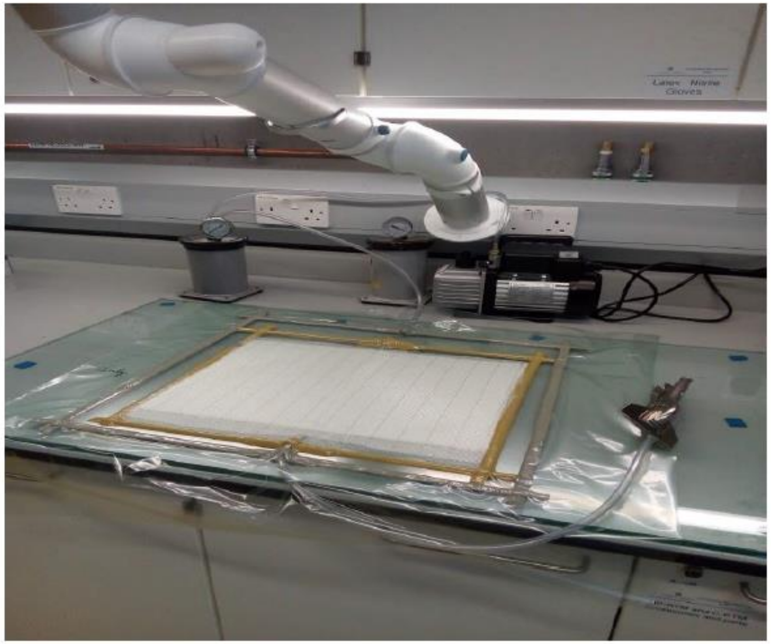
	Thick Laminate ~ 16 mm	Thin Laminate ~ 2.5 mm
Manufacturer	IXblue SHIPYARD, FRA	ULIM, IRE
Resin:	LEO Injection Resin 8500 from BÜFA	
Reinforcement:	SAERTEX U-E-940 g/m^2-LEO UD	
Curing schedule:	Infusion resin temp: 18°C, Mixing ratio: 2% peroxide, Post cure: 6 hours@80°C	Infusion resin temp: 17°C, Mixing ratio: 2% peroxide, Post cure: 6 hours@80°C
Lay-up	$[0]_{26}$ (26 layer)	$[0]_{2S}$ (4 layer)
Test sample size & Span/thickness ratio	500 x 30 x ~16 mm 25:1	200 x 25 x ~2.5 mm 30:1
Sample Orientation	Longitudinal & Transverse	Longitudinal & Transverse
Conditioning prior to testing:	None	Dried for 4 hours at 45°C

Manufacture

Manufacture of thin laminates at ULIM

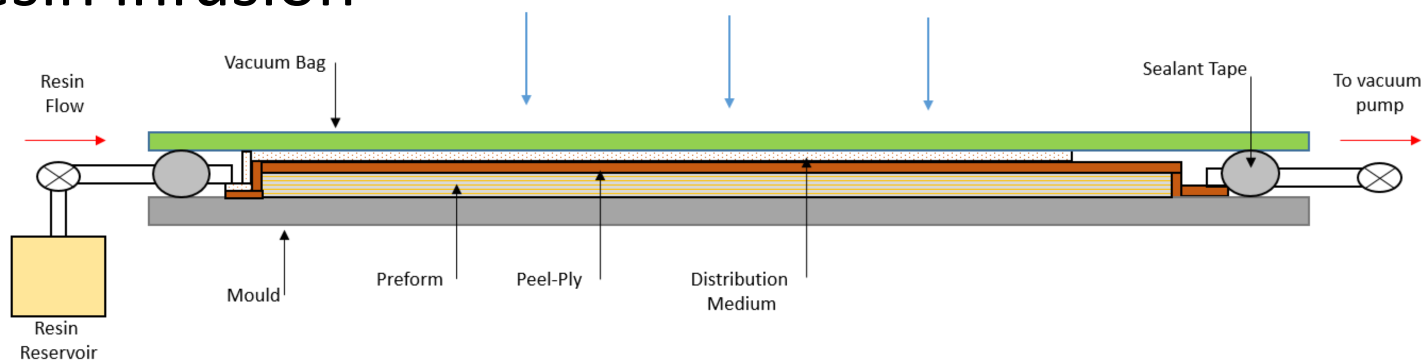


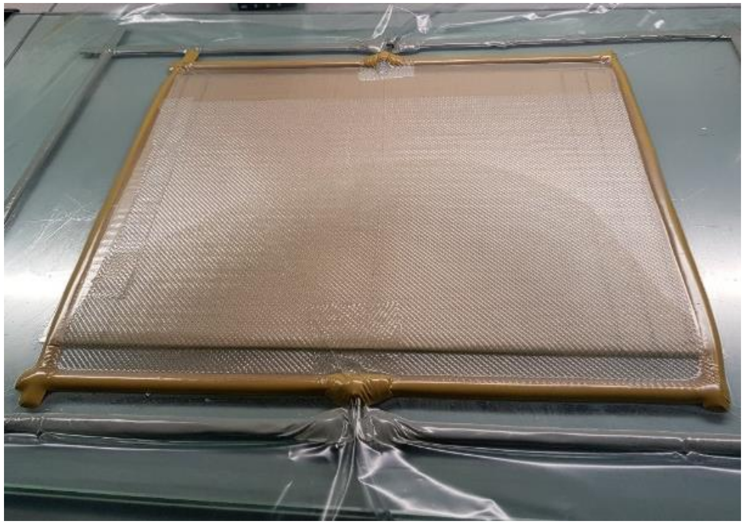


- All laminates nominally: 350 x 500 x 2.5 mm
- Lay-up: 0_{2S} (4 layers of NCF in a UD configuration)
- SAERTEX U-E-940 g/m^2-LEO UD

Manufacture

Liquid resin infusion





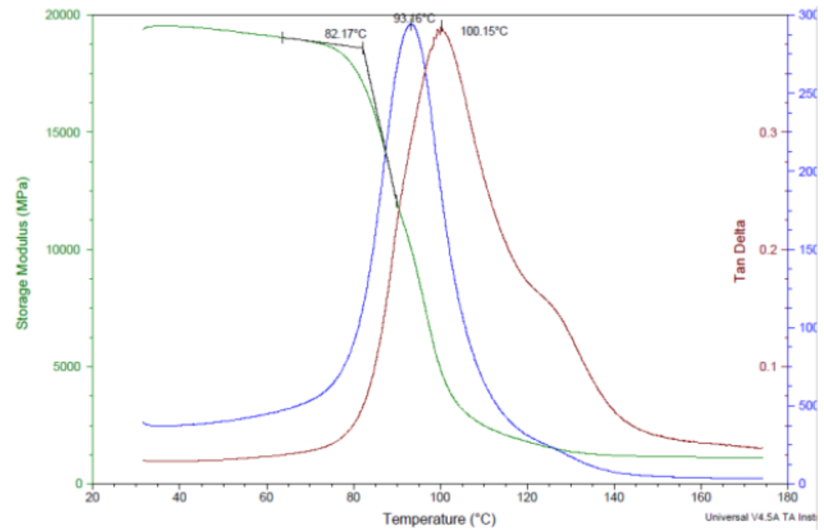
Infusion, cure and post cure schedule in line with manufacturers guidelines

Coated and uncoated thin laminates

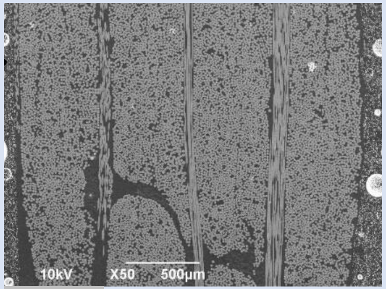
Quality Control (thin)

Material	Cured Ply Thickness	FVF
VE	0.71 mm	52%
PE	0.73 mm	54%
EP	0.74 mm	53%
TP	0.72 mm	55%

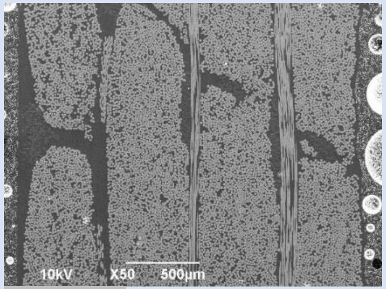
Tg and degree of cure



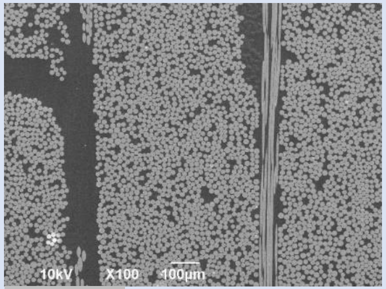
Void Analysis (MS 0051)



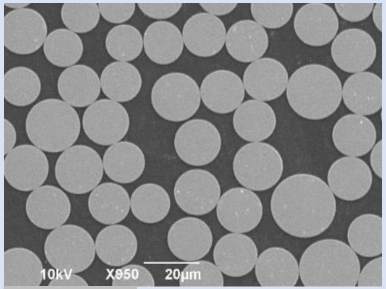
x50



x100



x100



x950

Testing

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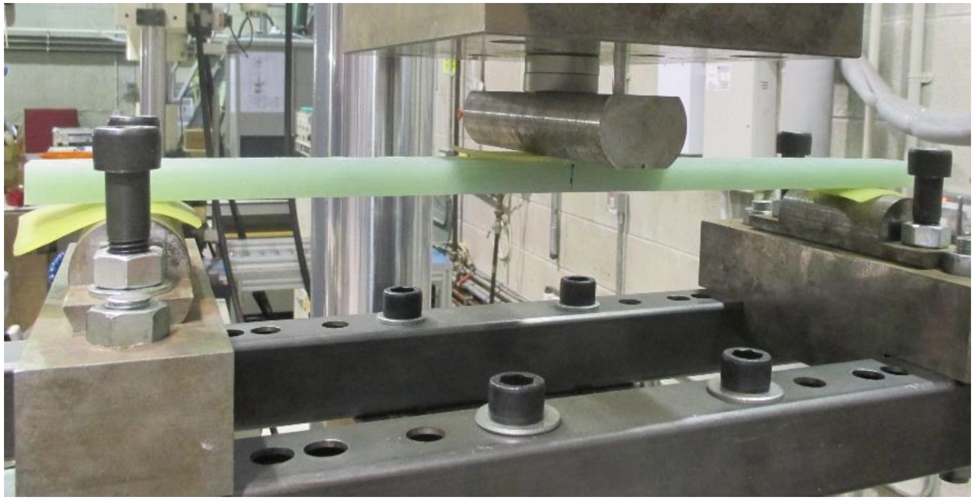
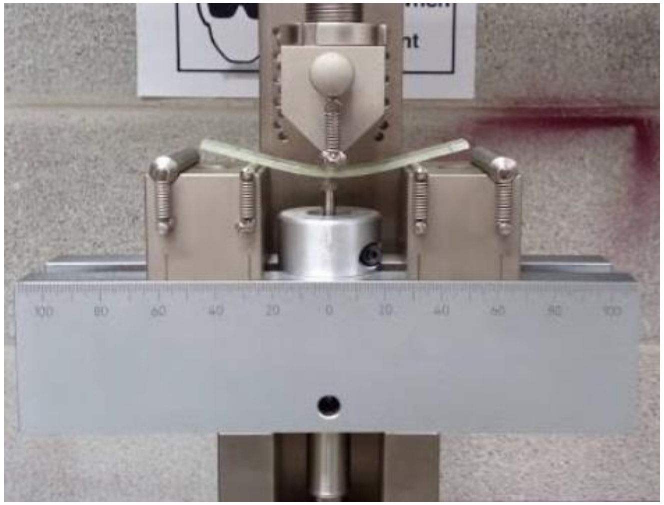
Thick Laminate

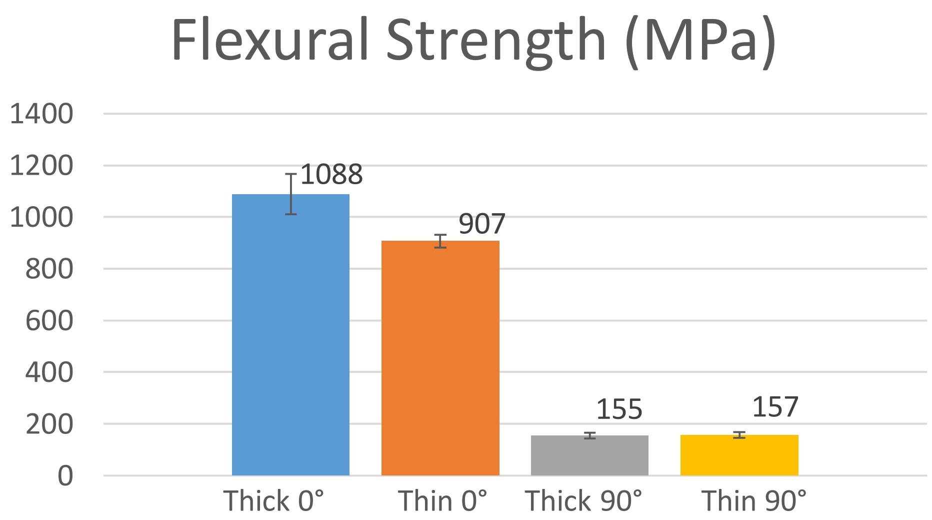


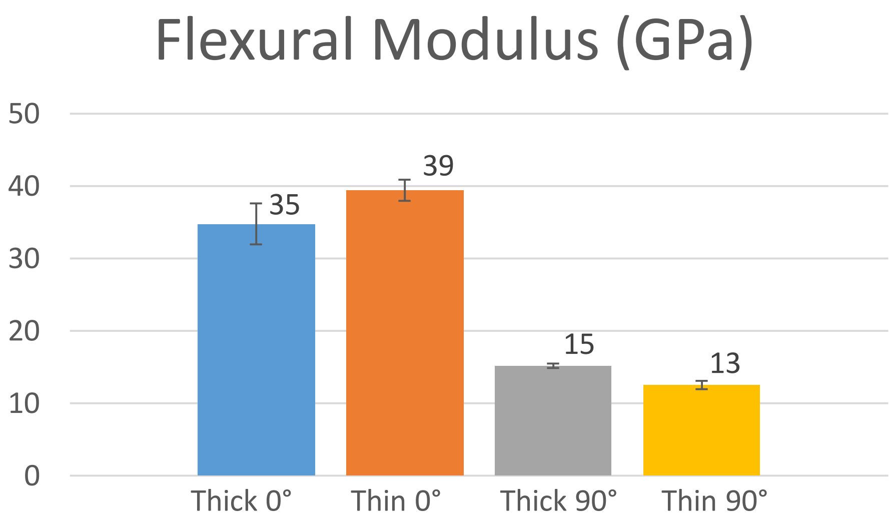
Thin Laminate



3-pt bend quasi-static loading arrangement

Results



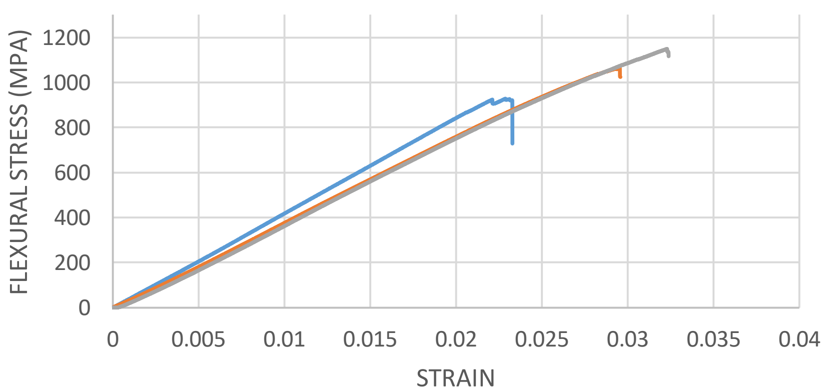


Coefficient of variation < 10 % in all cases

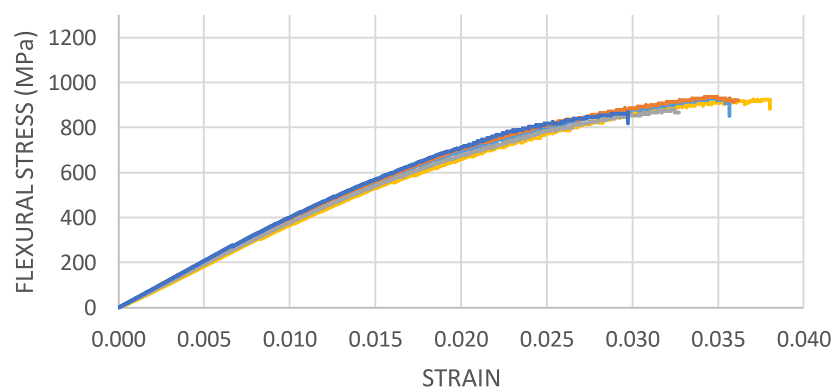
0° test samples

	Thickness (mm)	Cured ply thickness (mm)	Fibre volume[1] (%)	Span to thickness ratio	Flexural Strength (MPa)	Flexural Modulus (GPa)	Strain at failure (%)	Density[2] (g/cm^3)
Thick (x6)	16.6	0.64	58	25.3	1088	34.8	3.0	1.98 (x5)
Thin (x5)	2.6	0.66	56	30.4	907	39.4	3.4	1.97 (x16)

Thick

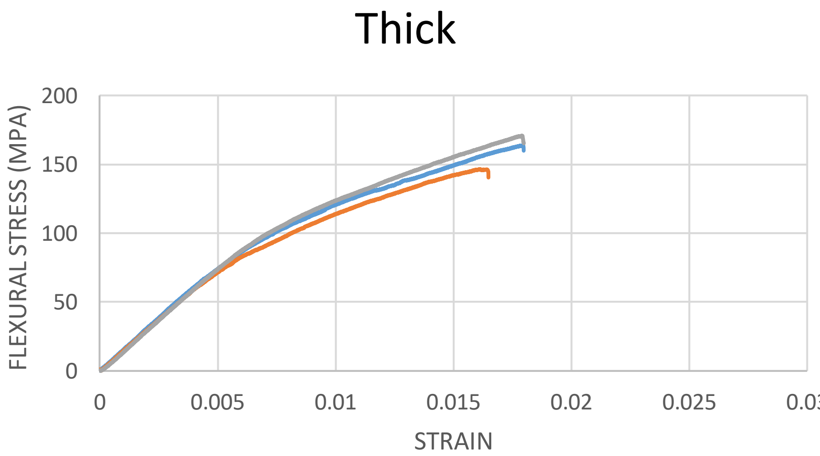


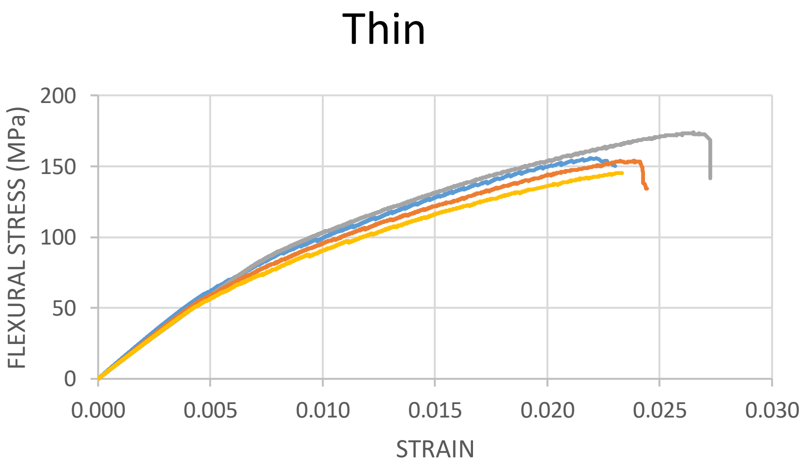
Thin



90° test samples

	Thickness (mm)	Cured ply thickness (mm)	Fibre volume[1] (%)	Span to thickness ratio	Flexural Strength (MPa)	Flexural Modulus (GPa)	Strain at failure (%)	-
Thick (x5)	16.2	0.63	59	25.3	155	15	1.7	-
Thin (x4)	2.7	0.68	54	29.6	157	13	2.5	-





Failure Modes

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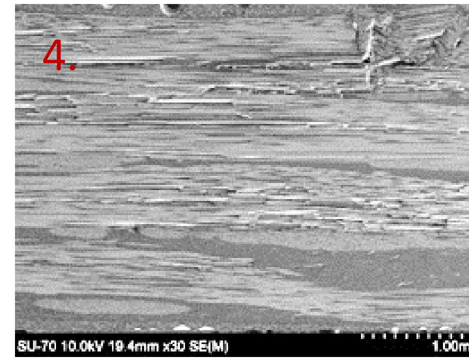
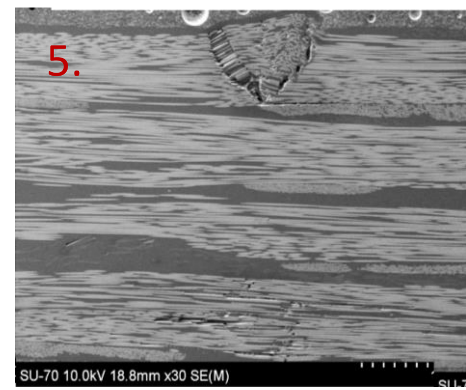
Thick 0°





Thin 0°

Conclusions

- A study has been performed to evaluate the mechanical properties of thick laminates manufactured in a shipyard environment and thin laminates manufactured in a laboratory environment using the same materials and cure schedule

- Properties evaluated include flexural strength, flexural modulus, density, fibre volume fraction and cured ply thickness

- The physical properties (density, fibre volume fraction and cured ply thickness) were confirmed to be essentially equivalent

- 0° 3-pt bend: shipyard samples showed a +20% increase in strength and a -12 % reduction in modulus relative to the laboratory samples. Failure mode was by compression under the load nose for both cases

- 90° 3-pt bend: shipyard samples showed a -1.2% reduction in strength and a +15% increase in modulus

- These variations are within the limits of variation expected.

Future Work

- In future work, samples will be extracted from a variety of locations on the hull of the demonstrator (~ 25 mm thick) to evaluate various properties of large thick laminates manufactured under shipyard conditions:

Acknowledgements

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Thank you for your attention

www.fibreship.eu

http://cordis.europa.eu/project/rcn/210787_en.html