Benchmarking mechanical assessment of adhesive bonding and hybrid structural joining techniques implemented in maritime industries

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Advanced Joining Processes Unit

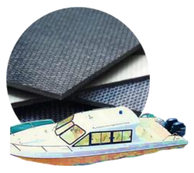
Introduction

Marine Industry

Marine industry as the backbone of international trade

Concerning issues in using **conventional metallic materials**: lack of **weight/fuel efficiency**, low **fatigue resistance**, and **electrolytic corrosion**

Progresses towards **sustainability**, adopting technologies to meet ambitious carbon dioxide reduction

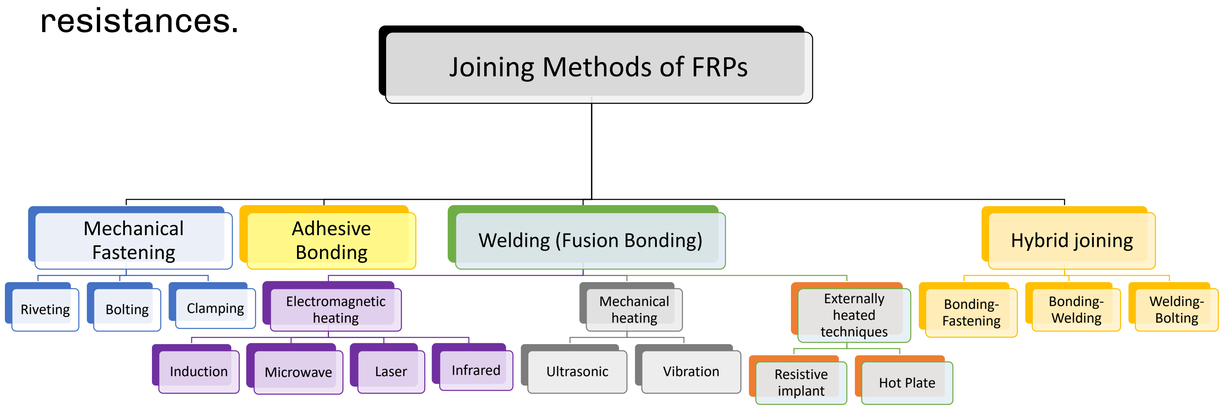


- High **strength to weight ratio**
- High **fatigue failure resistance**
- good **corrosion resistance**.
- Good **vibration damping** and **noise absorption** acceptable performance against **fire**

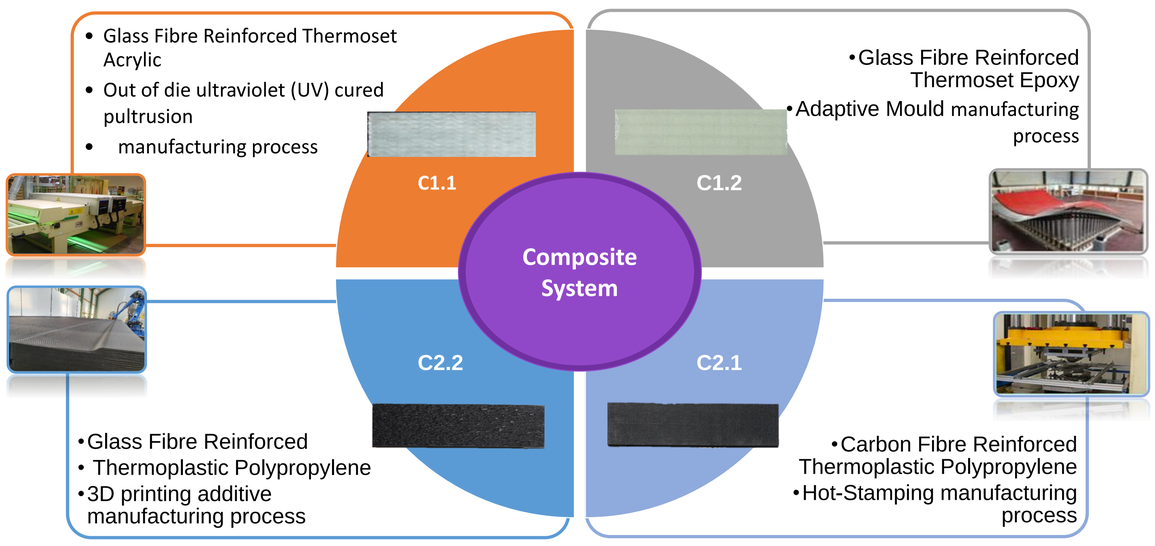
Why Joining is important?

- **Shape the panels** into a large and complex structure
- **Connect and transfer** applied load between the substructures
- Maintain the ship **stiffness under different loadings**
- Maintain the **reliability and durability** of the of the whole structures

Currently, and depending on the materials to be joined, in the maritime industry, a wide range of joining techniques can be used such as **mechanical fastening, welding (fusion bonding), adhesive bonding and hybrid joining** [2,3]. It is however, considered that the joining techniques that use structural adhesives are the most versatile, being able to join dissimilar materials with very interesting mechanical resistances.



Motivation

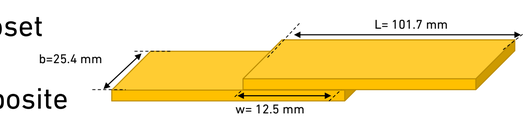


Experimental Details

Considered Configurations for the Assessment of Joining Techniques

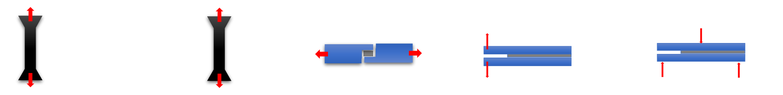
Adhesive Bonded Joints						Bolted Joints						Hybrid Bonded-Bolted Joints							
C1.1/C1.1	C1.2/C1.2	C2.2/C2.2	C1.1/C1.2	C1.1/C2.2	C1.2/C2.2	C1.1/C1.1	C1.2/C1.2	C2.2/C2.2	C1.1/C1.2	C1.1/C2.2	C1.2/C2.2	C1.1/C1.1	C1.2/C1.2	C2.2/C2.2	C1.1/C1.2	C1.1/C2.2	C1.2/C2.2	C1.1/C2.1	C1.2/C2.1

- C1.1: Thermoset Photocurable acrylate matrix thermoset FRP composite
- C1.2: Thermoset Epoxy resin matrix thermoset FRP composite
- C2.1: Thermoplastic hot-stamped FRP Composite
- C2.2: Thermoplastic 3D printed FRP Composite

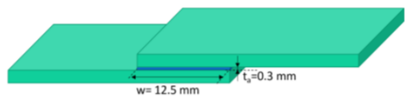


Adhesive Bonding

PLEXUS



Mechanical Property	Tensile Strength (MPa)	Young Modulus (MPa)	Shear Strength (MPa)	Tensile Fracture Energy (N/mm)	Shear Fracture Energy (N/mm)
Value	14.6±2%	668±6%	11.6±15%	2.4±11%	8.6±13%
Standard	ASTM D638-14	ASTM D638-14	ASTM D5656	ASTM D3433	ASTM D7905



Bolting

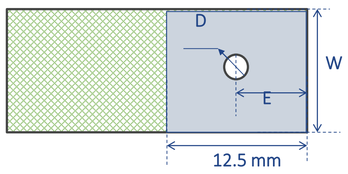
Stainless steel **M2** bolt class 70

Effective Parameters

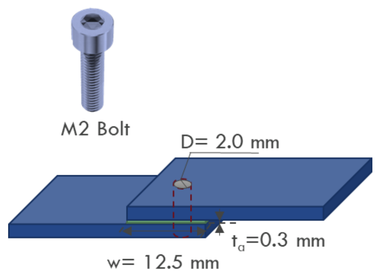
- W/D (width of substrate to diameter of the bolt)
- E/D (edge distance to diameter of the bolt)
- Clearance between bolt and hole ➡ Damage
- Clamping Torque ➡ Friction Coefficient

3≤W/D

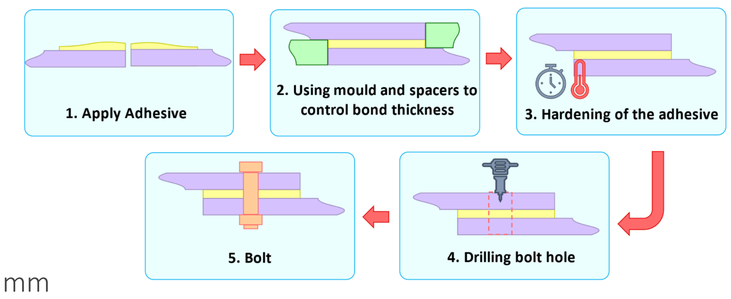
3≤E/D



Hybrid Bonding-Bolting

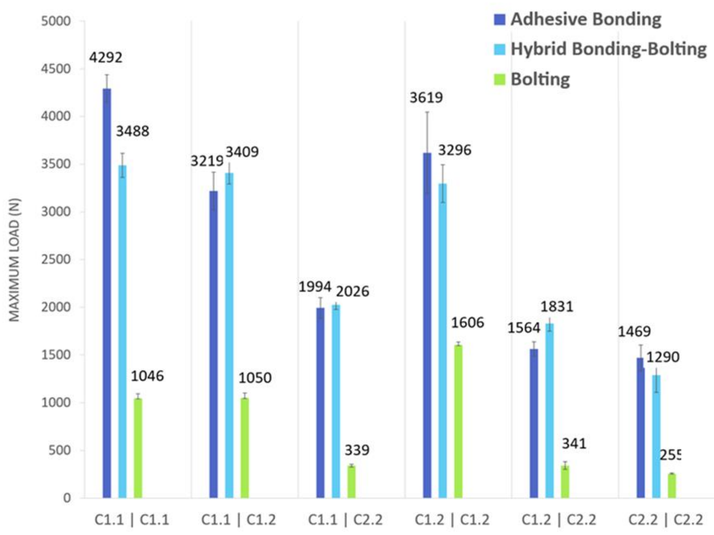


Applied Clamping Torque: 0.6-0.7 Nmm



Results and Discussion

Comparative strength of the tested single lap joints manufactured by adhesive bonding, bolting and hybrid bonding-bolting



Material		Adhesive bonding	Bolting	Hybrid Bonding-Bolting
Thermoset to thermoset	C1.1-C1.1	Cohesive	Bearing	Cohesive+Bearing
	C1.2-C1.2	Cohesive	Bearing	Cohesive+Bearing
	C1.1-C1.2	Cohesive	Bearing	Cohesive+Bearing
Thermoset to thermoplastic	C1.1-C2.2	Mixed (Cohesive+Adhesive)	Cleavage	Adhesive + Cleavage
	C1.2-C2.2	Adhesive	Cleavage	Adhesive + Cleavage
	C1.1-C2.1			Adhesive + Bearing
	C1.2-C2.1			Adhesive + Bearing

Conclusion

Similar thermoset composites: adhesively bonded joining is highly recommended > most feasible method > provide higher strength rather than other techniques.

Dissimilar thermoset composites: hybrid joining > efficient > higher strength rather than adhesive bonding and boltingfail-safe mechanism is another prominent advantage of this method and must be considered

Joining of thermoplastic materials: significant challenge

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