ONE EIGHTY
MATERIALS ENGINEERING SOLUTIONS

COMPOSITES IN THE MARINE INDUSTRY

SARAH VIRGIN

COMPOSITES IN THE MARINE INDUSTRY

1. Composites as an Engineering Material
2. Composite Properties vs Metal Properties
3. Verification of Quality Control by way of Material and Mechanical Testing
4. Compliance through Quality Assurance

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MATERIALS ENGINEERING SOLUTIONS

COMPOSITES AS AN ENGINEERING MATERIAL

- Carbon Fibre Laminates
- Glass Fibre Laminates
- Sandwich Composites

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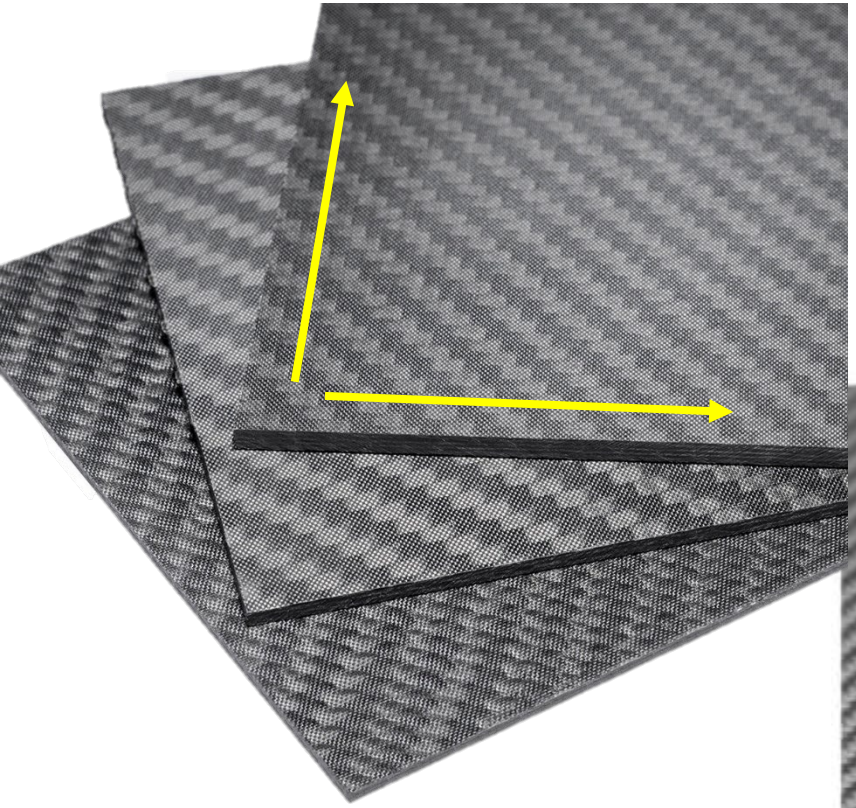
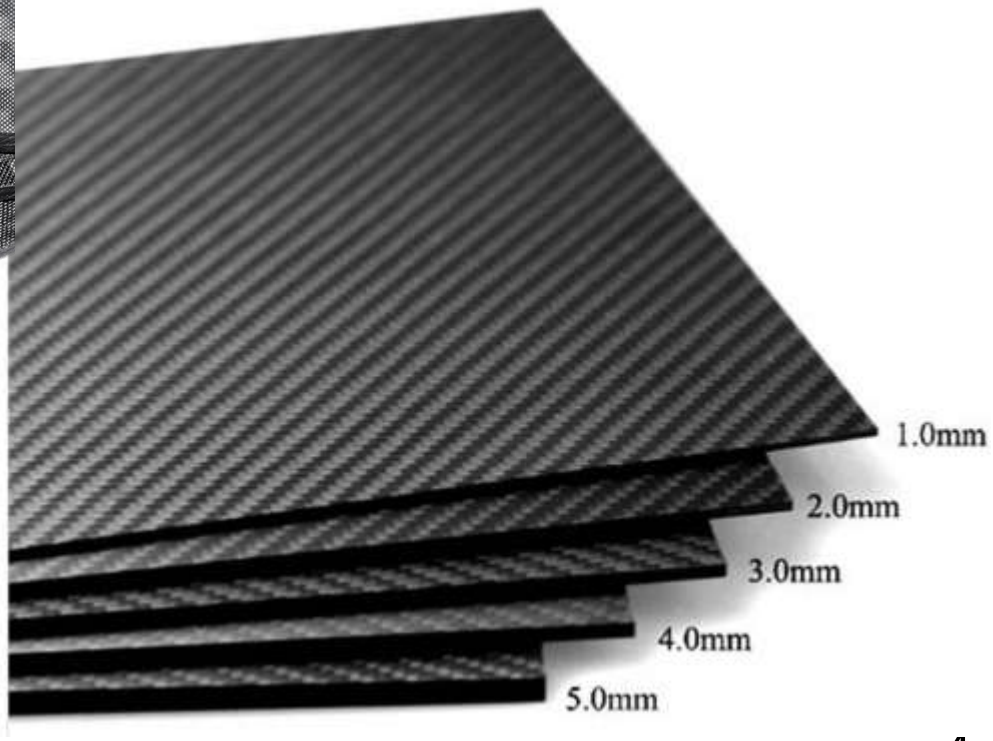
COMPOSITES AS AN ENGINEERING MATERIAL



Carbon Fibre Laminates



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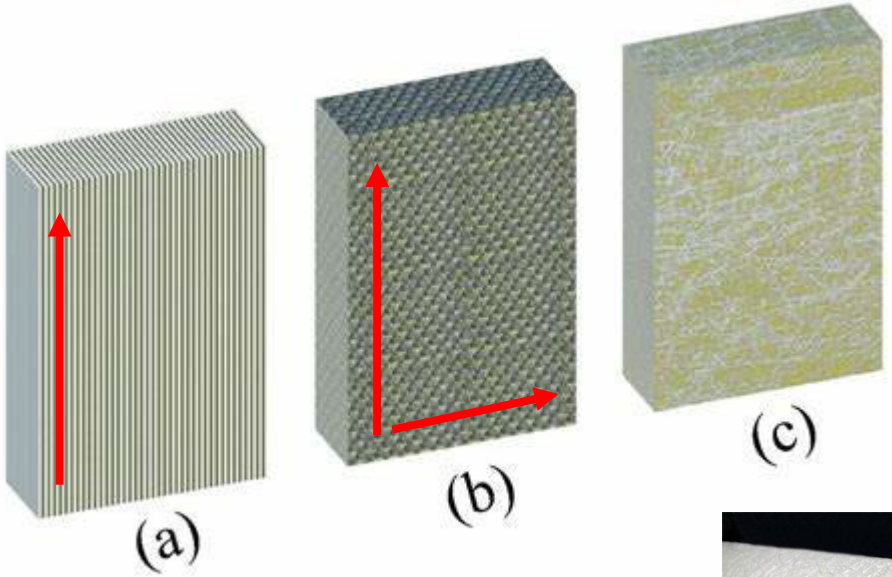
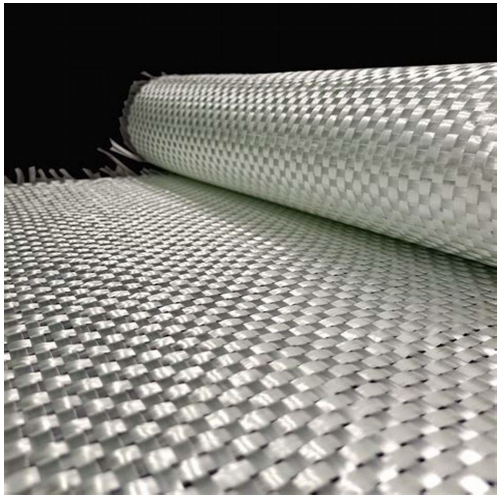


Glass Fibre Laminates



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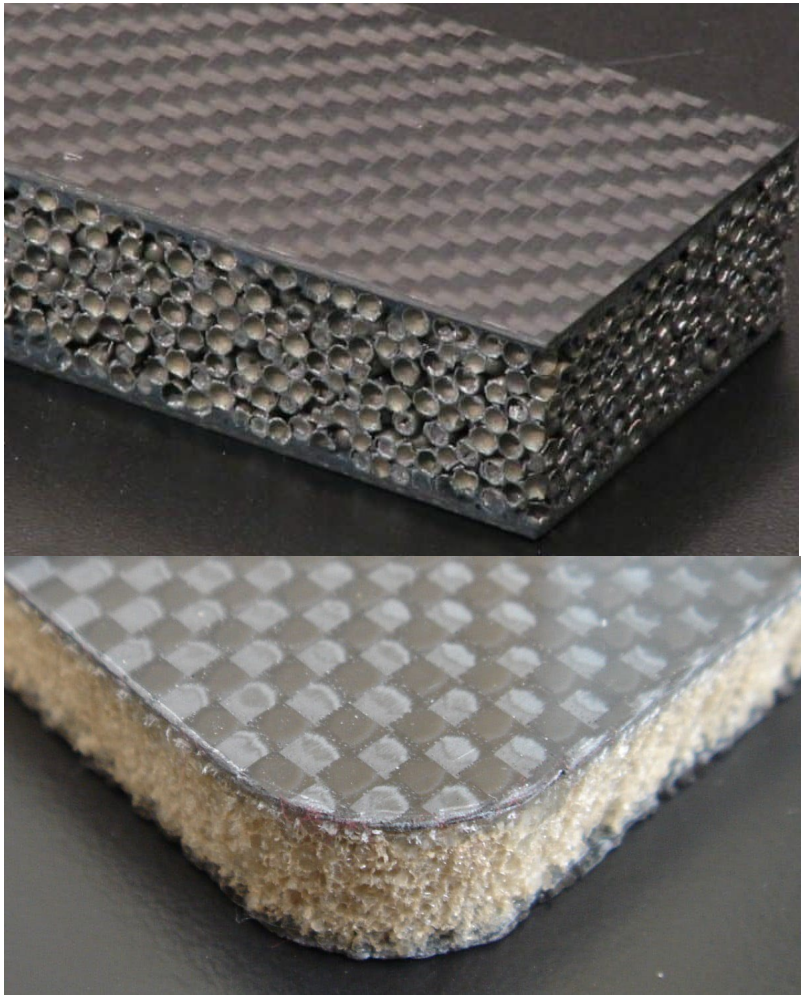
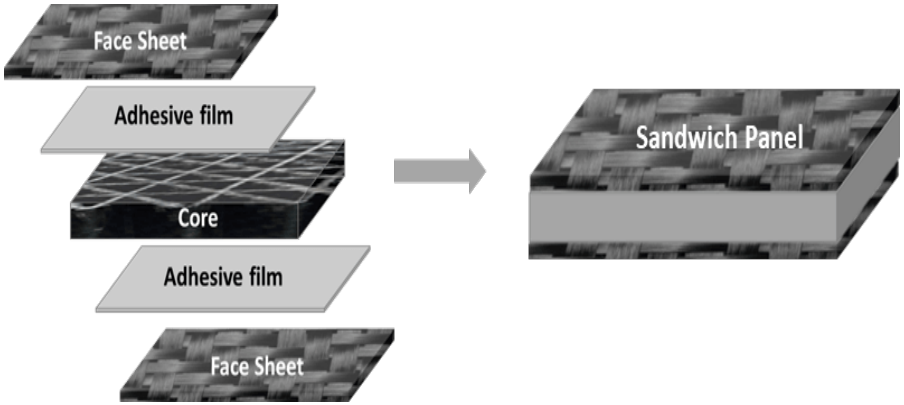
COMPOSITES AS AN ENGINEERING MATERIAL



Sandwich Composites



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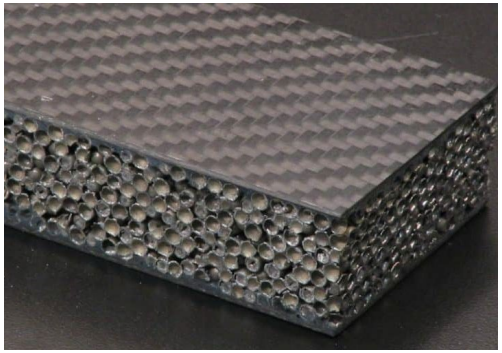
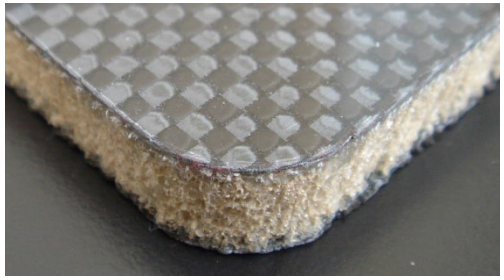
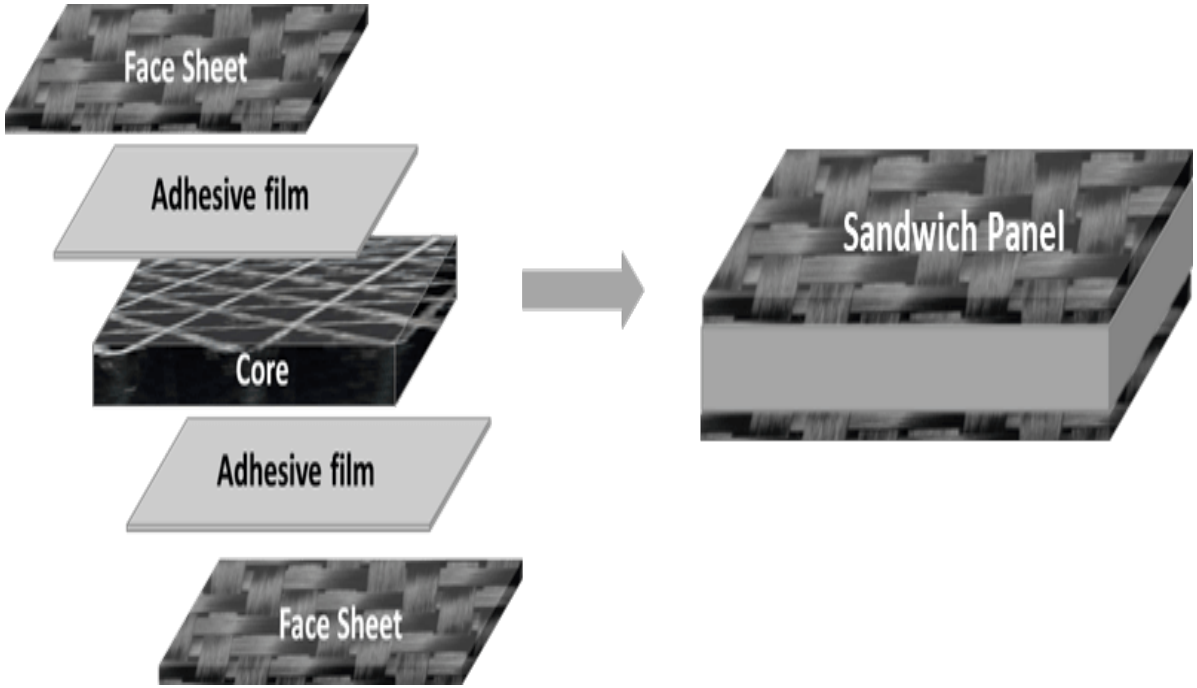


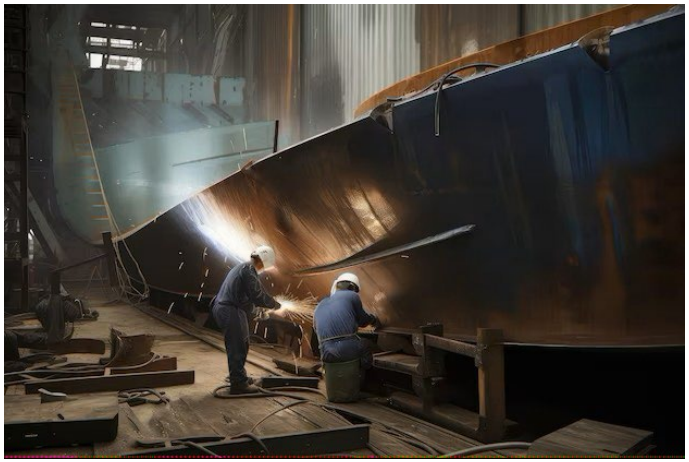


Sandwich Composites



COMPOSITES AS AN ENGINEERING MATERIAL

- Molds vs Welds
  - Hulls
  - Cabins
  - Decking…



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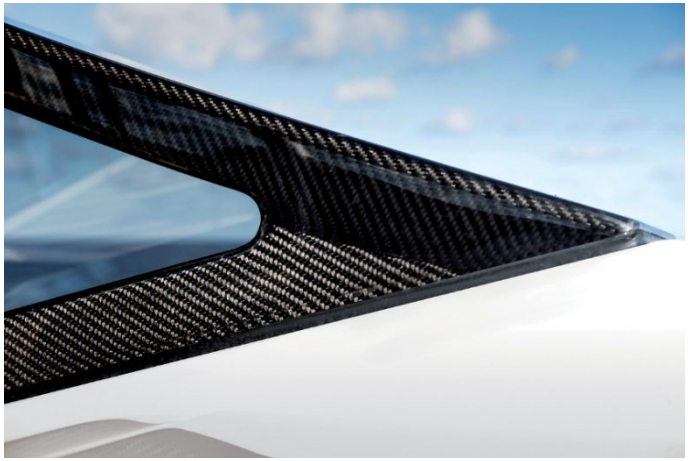
COMPOSITES AS AN ENGINEERING MATERIAL

- Bulkheads
- Ceilings
- Repairs, etc.



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COMPOSITES IN THE MARINE INDUSTRY

1. Composites as an Engineering Material
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MATERIALS ENGINEERING SOLUTIONS

COMPOSITE PROPERTIES VS METAL PROPERTIES

1. Density

- Composites
  - Lightweight
  - Fuel Efficient → Reduce Carbon Footprint
  - Carbon Fibre ~ 1600 – 2000 kg/m³
  - Glass Fibre ~ 1600 – 2700 kg/m³
  - Foam Core of Sandwich Composites (PVC) ~ 100 kg/m³

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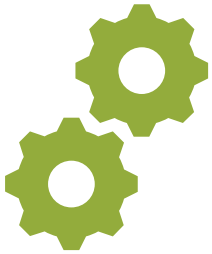
MATERIALS ENGINEERING SOLUTIONS

COMPOSITE PROPERTIES VS METAL PROPERTIES

1. Density

- Metals
  - Aluminium ~ 2700 kg/m³, but
  - Structural Steel ~ 7500 – 8000 kg/m³



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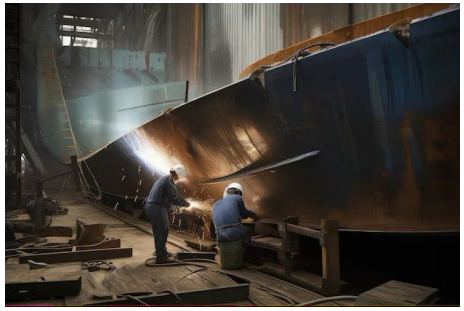
MATERIALS ENGINEERING SOLUTIONS

COMPOSITE PROPERTIES VS METAL PROPERTIES

2. Flexural / Bend Properties

- Metals
  - Weld Defects ~ Voids, Cracking in the Fusion Line
  - Go/No-Go Test
  - Require Good Flexural Properties for Manufacturing



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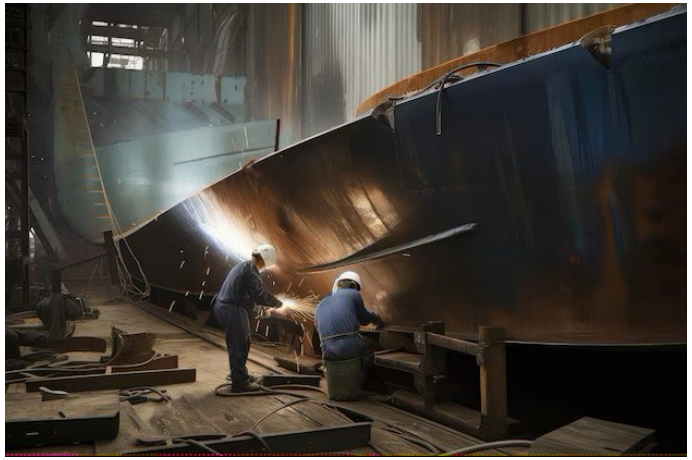

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MATERIALS ENGINEERING SOLUTIONS

COMPOSITE PROPERTIES VS METAL PROPERTIES

2. Flexural / Bend Properties

- Composites
  - Not required to “bend” to manufacture
  - Can sometimes achieve a more complex shape or design of a hull
  - Delamination in Laminates
  - Point of Adhesion Failure for Sandwich Composites

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MATERIALS ENGINEERING SOLUTIONS

COMPOSITE PROPERTIES VS METAL PROPERTIES

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MATERIALS ENGINEERING SOLUTIONS

COMPOSITE PROPERTIES VS METAL PROPERTIES

3. Impact Properties

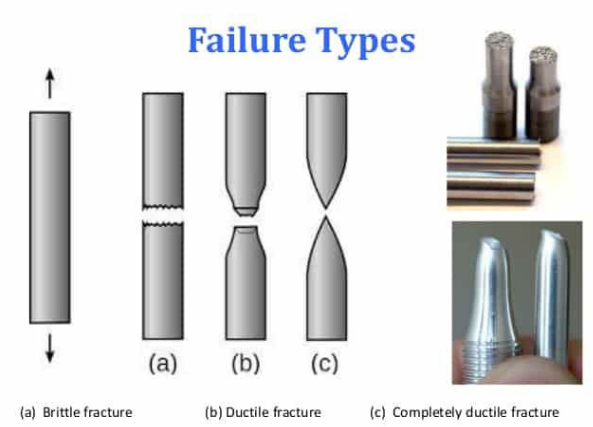
- Metals
  - Charpy V-Notch
  - Ductility
  - Quick check for material toughness
  - Particularly for S355JR / S355J2, etc. materials
  - Not meant for drop impacts

- Composites
  - Drop Impact
  - Typically sandwich composites
  - Effect of a sharp impact
  - Different thermal coefficients → microcrack; therefore, not as well suited for icy waters

COMPOSITE PROPERTIES VS METAL PROPERTIES

4. Tensile Properties

- Metals
  - Exact same principles that govern composites
  - Different failure modes
  - Welded Joints
  - UTS of S355JR ~ 450-680 MPa
  - UTS of Aluminium 6061 ~ 290 MPa



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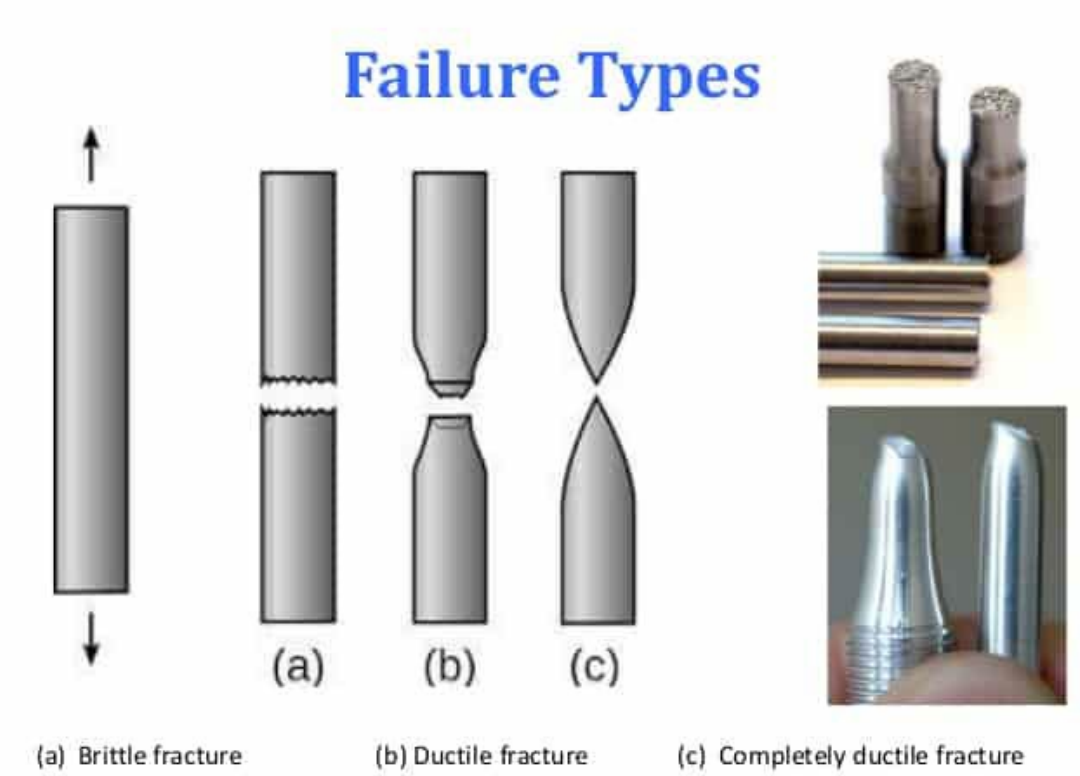

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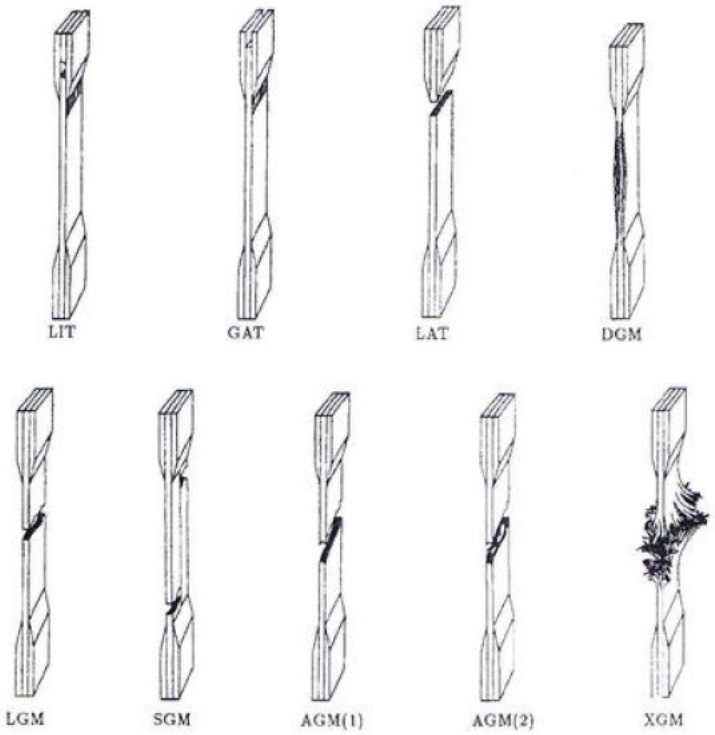
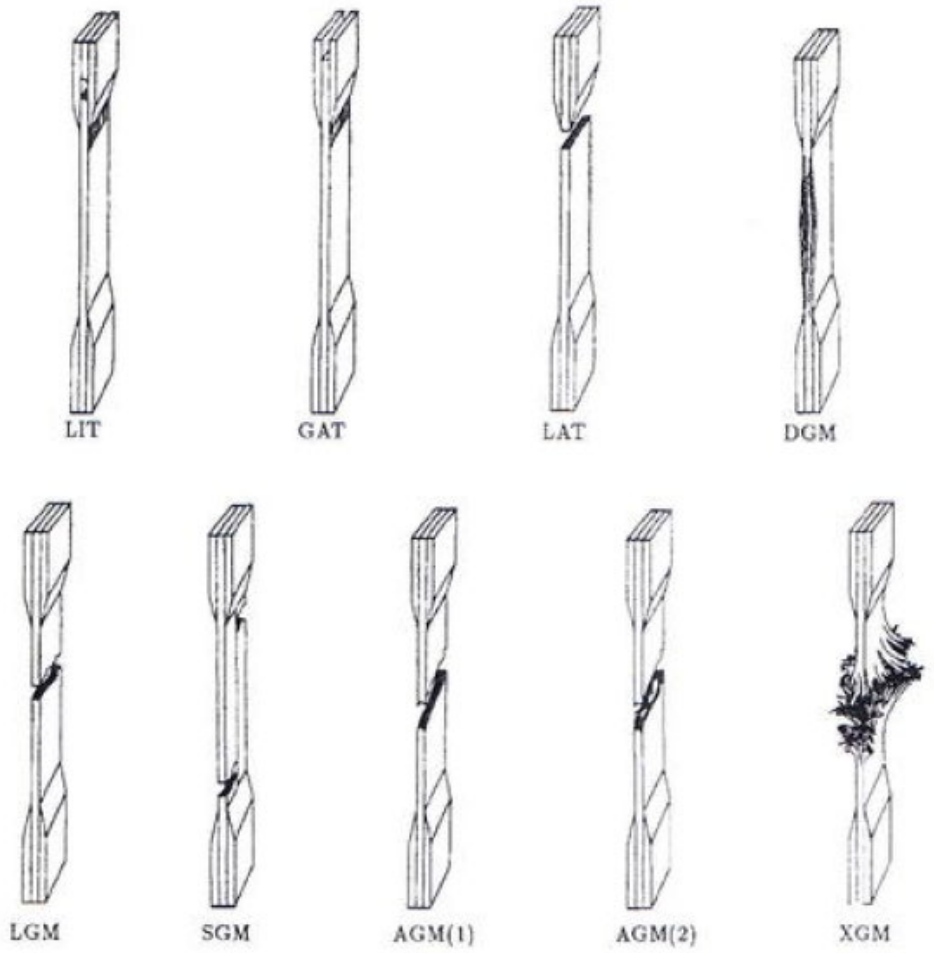
COMPOSITE PROPERTIES VS METAL PROPERTIES

4. Tensile Properties

- Composites
  - Delamination / Splitting / Lateral Explosive, etc.
  - Longitudinal vs Transverse
  - UTS of Carbon Fibre ~ 900 MPa
  - UTS of Glass Fibre ~ 180 MPa



COMPOSITE PROPERTIES VS METAL PROPERTIES



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COMPOSITES IN THE MARINE INDUSTRY

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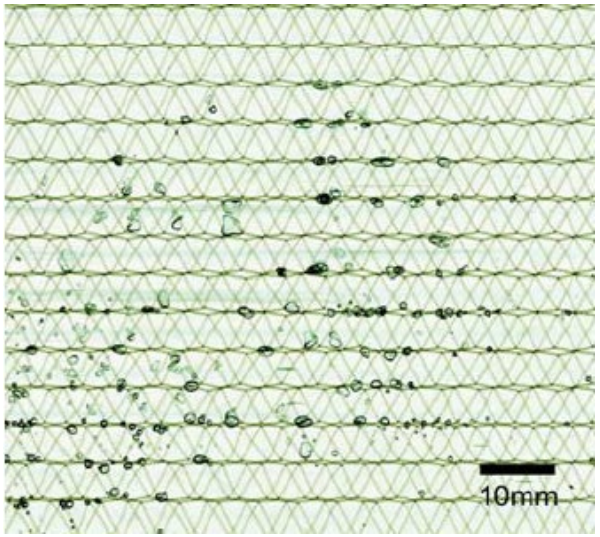
MATERIALS ENGINEERING SOLUTIONS

VERIFICATION OF QUALITY CONTROL BY WAY OF MATERIAL AND MECHANICAL TESTING



1. Density – Mass per Volume

- Relatively quick test
- Check for voids
- Ensure correct materials were used
- Important for fuel efficiency calculations and FEA simulations

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MATERIALS ENGINEERING SOLUTIONS

ENSURING QUALITY CONTROL BY WAY OF MATERIAL AND MECHANICAL TESTING

2. Reinforcement Content by Weight

- Compliments the density test
- Determination of the percentage of fibres that are within the laminate skin
- Ensure correct layup was used (Manufacturing QC)
- Design Specifications

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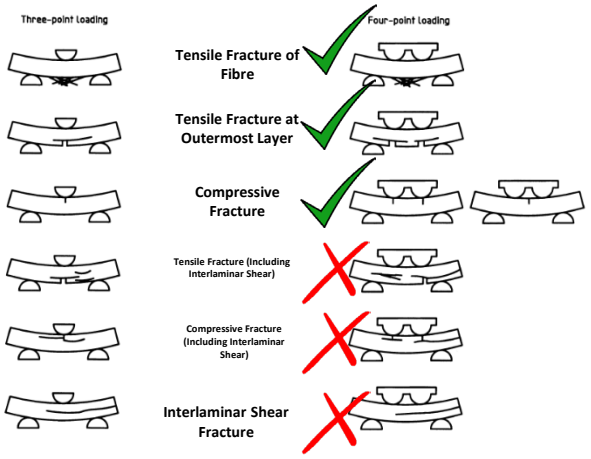
MATERIALS ENGINEERING SOLUTIONS

VERIFICATION OF QUALITY CONTROL BY WAY OF MATERIAL AND MECHANICAL TESTING

3. Flexural (3-Point Bend) Testing

- Deflection before failure
- Deflection aids design models
- Failure mode
- Interlaminate shear is prohibited
- Sandwich Composite – Adhesion of foam core to laminate skin



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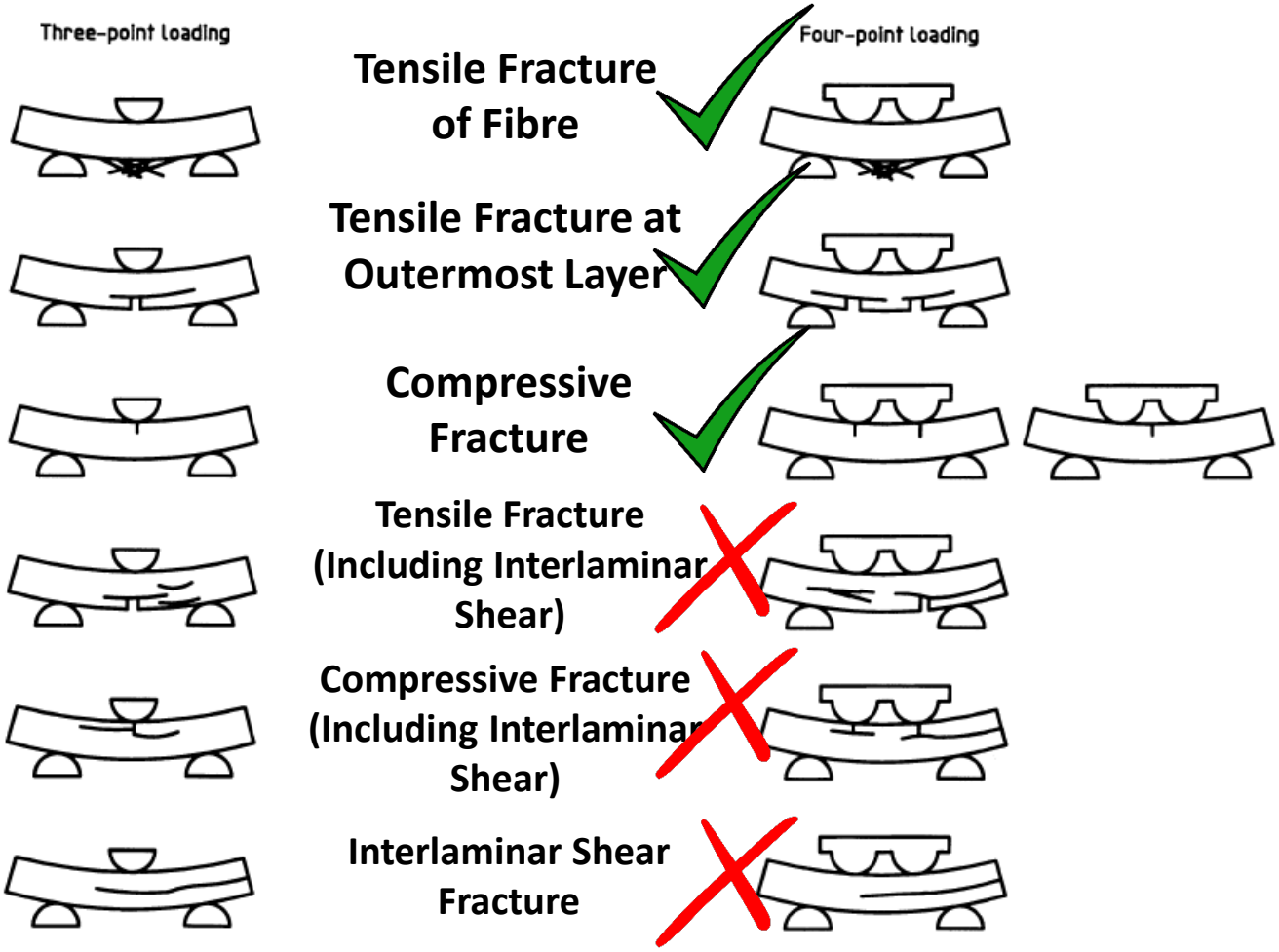
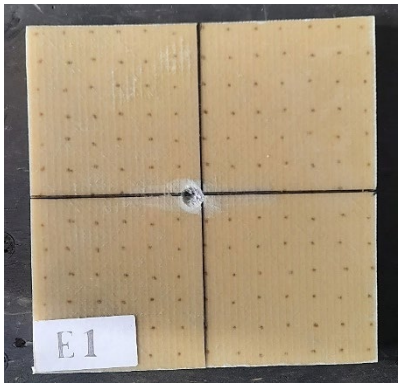
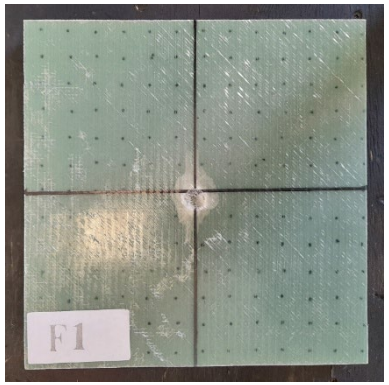


VERIFICATION OF QUALITY CONTROL BY WAY OF MATERIAL AND MECHANICAL TESTING

4. Impact Testing

- Drop impacts simulate small high-velocity impacts
- Skye Advance: Sandwich composites faired better than Aluminium at certain impact weights





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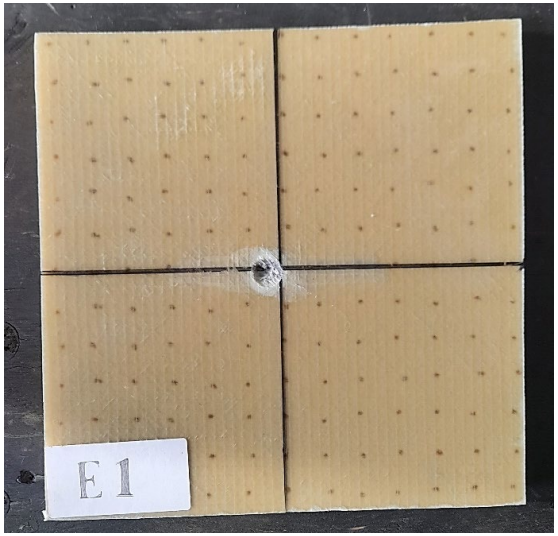

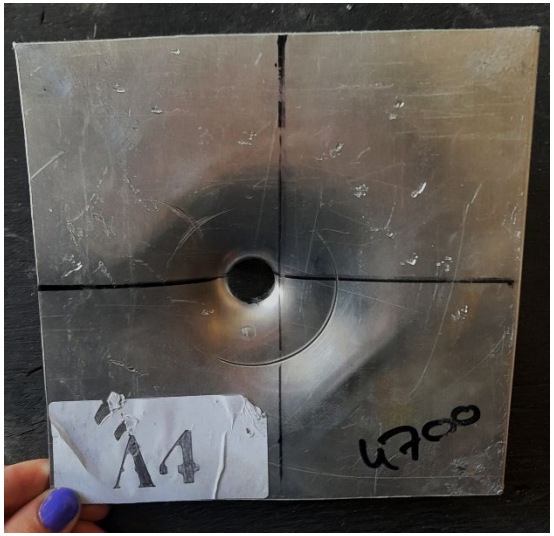

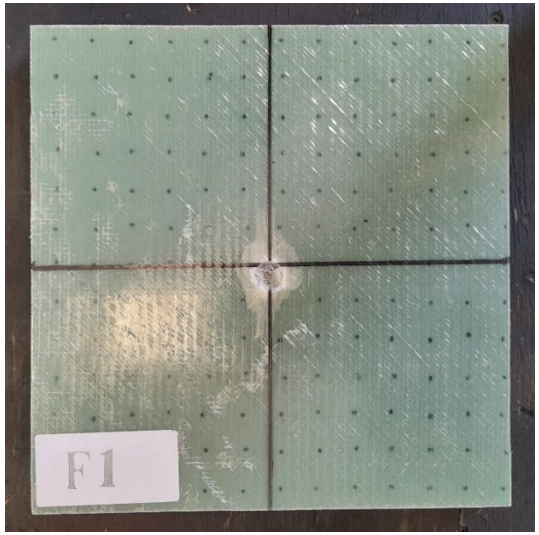

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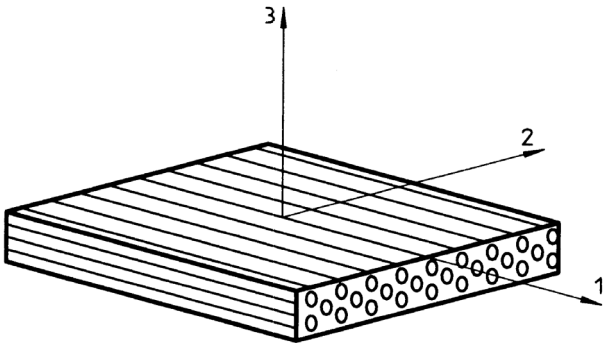
VERIFICATION OF QUALITY CONTROL BY WAY OF MATERIAL AND MECHANICAL TESTING

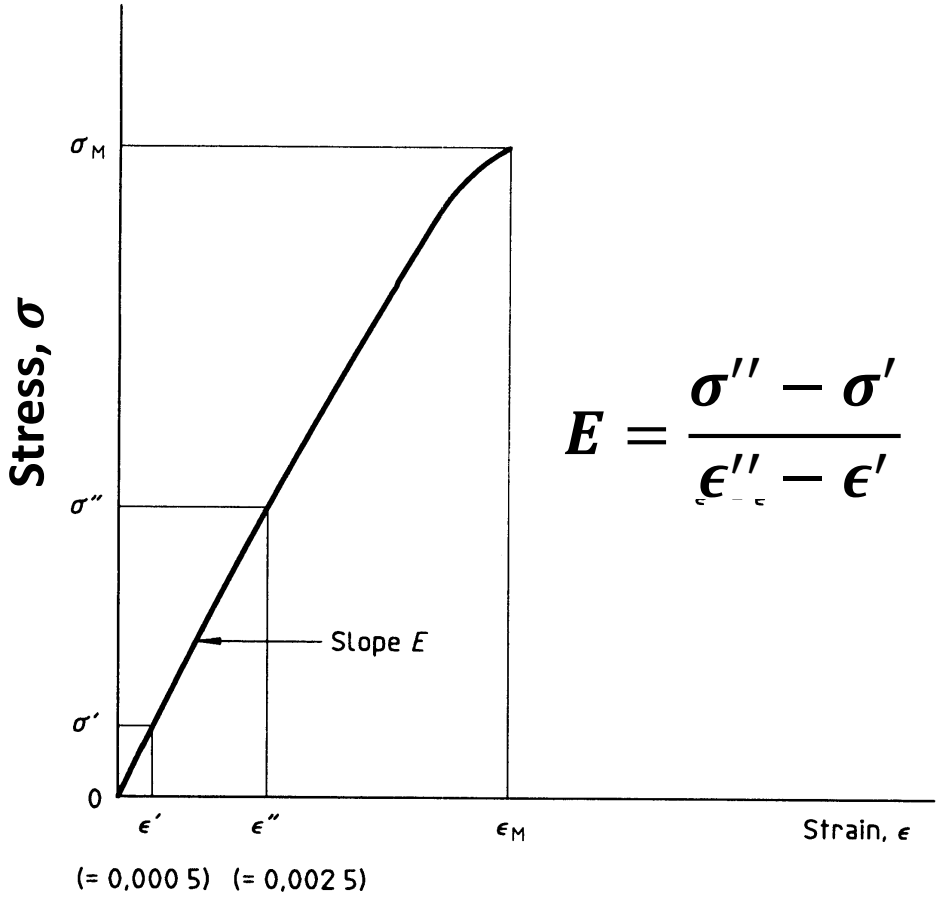
5. Tensile Testing

- Longitudinal vs Transverse – Consider whether isotropic
- Same principle as metals
- Important to understand from a design-, purchasing-, and maintenance perspective
- Tensile properties are crucial to the CFD and FEA simulations during the design process to ensure that the models are accurate and meet the loading requirements of the design

VERIFICATION OF QUALITY CONTROL BY WAY OF MATERIAL AND MECHANICAL TESTING

5. Tensile Testing





$$E = \frac{\sigma'' - \sigma'}{\epsilon'' - \epsilon'}$$

VERIFICATION OF QUALITY CONTROL BY WAY OF MATERIAL AND MECHANICAL TESTING

5. Tensile Testing

- Evolution Marine quality control test of their deck plate that appeared to have cured unevenly
- UTS of 111MPa (Internal Skin) vs 64MPa (External Skin) & 156MPa (Internal Skin) vs 99MPa (External Skin) - Post-cured a second time
- Outcome – Discovered that the center of the sandwich composite deck is below the expected UTS values, compared to the rest of the deck which resulted from improper curing during manufacturing and they were able to replace it before commissioning the yacht

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VERIFICATION OF QUALITY CONTROL BY WAY OF MATERIAL AND MECHANICAL TESTING

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VERIFICATION OF QUALITY CONTROL BY WAY OF MATERIAL AND MECHANICAL TESTING

6. Other Testing…

- Ultrasonic testing (UT) for void detection
- Lap Shear testing for shear properties and failures
- Differential Scanning Calorimetry to understand the curing phase
- Etc.

COMPOSITES IN THE MARINE INDUSTRY

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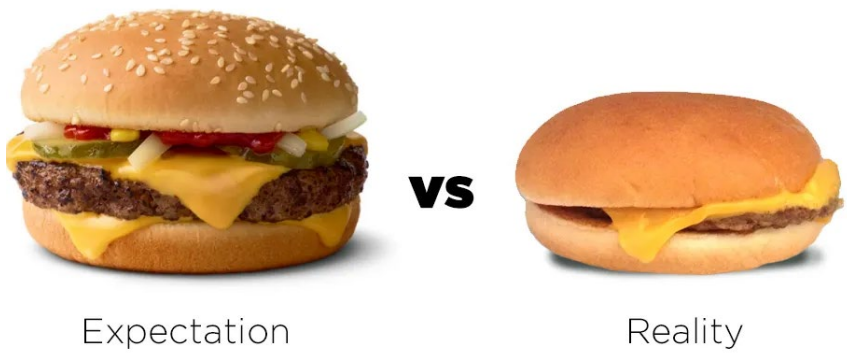
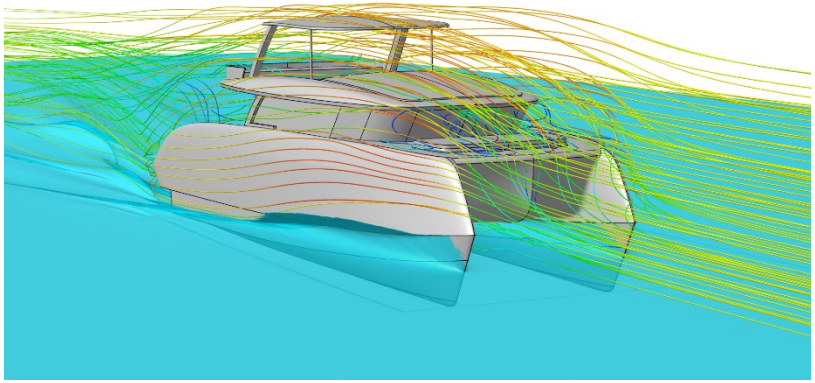
COMPLIANCE THROUGH QUALITY ASSURANCE

- Ensure Material Compliance
  - Material Properties vs Datasheets
  - Hold Suppliers Accountable

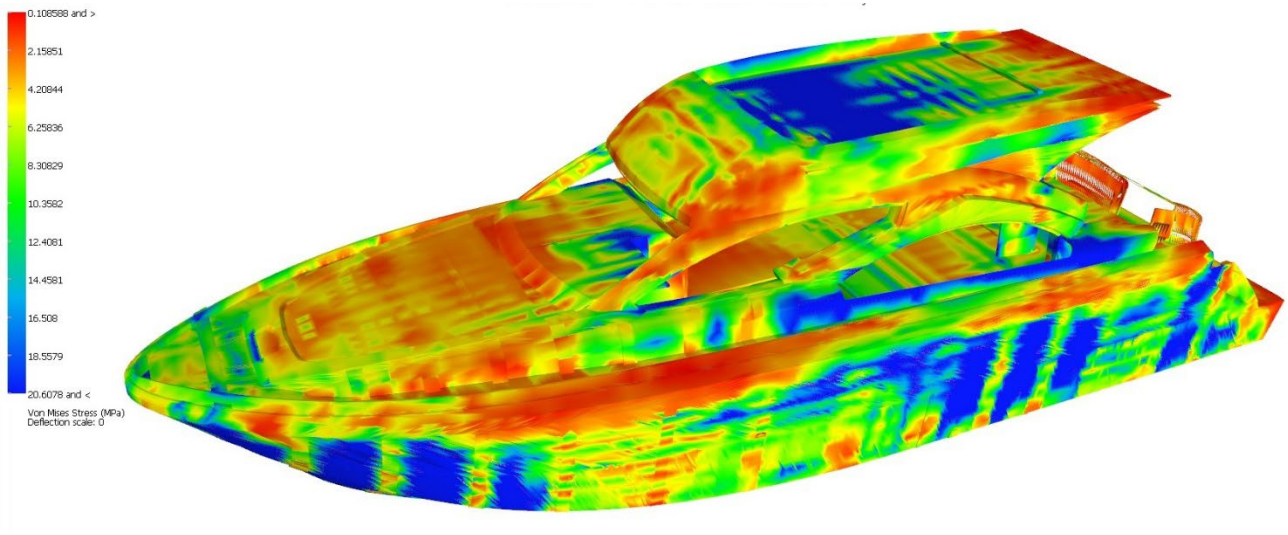


- Design / Manufacturing Quality Assurance
  - Compare with Theoretical Calculations
  - Improve CAD or CFD Models
  - Similar to a Weld Qualification



COMPLIANCE THROUGH QUALITY ASSURANCE

- Failure Mitigation
  - Ensure appropriate design from the project initiation
  - Identify Weak Areas and Recommend Improvements
  - Prevent Catastrophic Failures
- Traceability



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COMPLIANCE THROUGH QUALITY ASSURANCE

- Type Approval
  - Particularly for repeat products, i.e., same materials, same design, same molds…
  - Qualify once and if traceability is proven and documentation is up to date, then can repeat the product

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COMPLIANCE THROUGH QUALITY ASSURANCE

- Compliance
  - Reducing risks, means better chance of ensuring warranty claims from insurers…
    - traceability is key
    - classification
  - Increased lifespan (no unnecessary failures or repairs)
  - Improve designs which improves fuel efficiency, resulting in a boat with a lower carbon footprint
  - Build and ensure your reputation through the proof of safety and compliance
  - Proof that you built to an industry standard

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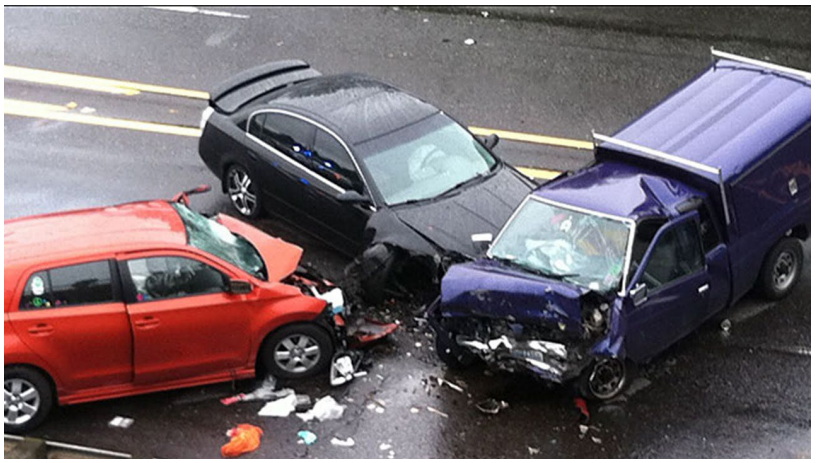
CONCLUSION: COMPOSITES IN THE MARINE INDUSTRY

- An Analogy:
  - Can you drive a car that is not road-worthy?
  - Can you drive a car without a driver's license?

  - Yes, you can, but the consequences are severe…



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CONCLUSION: COMPOSITES IN THE MARINE INDUSTRY

- Composites are extremely prevalent in the marine industry
- Material and Mechanical Testing can significantly improve and benefit the quality control procedure before-, during-, and after manufacturing with composites
- By ensuring quality assurance through compliance, not only will you reduce the risk of failure, the risk of litigation, and loss of product, but you will also gain in reputation by putting the client's safety first

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THANK YOU