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Study on Durability of Composite Marine Structure using FEA

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Abstract: Marine structures are subjected to a wide variety of loads that are cyclic in nature (e.g., storm winds, waves, and currents). The marine environment presents the biggest difficulty to researchers in terms of selecting a suitable material for structural purposes. The durability behavior of composite structures that can be encountered in marine structure is investigated here in this research. Through the use of FEA, the goal of this study is to identify the composite structure used in marine application and to investigate the behavior characteristic of composite structures in terms of impact test and flexural test. The Charpy impact test and three-point bending test were all carried out with the assistance of ANSYS Workbench. As reinforcing materials, chopped strand mat (CSM) and woven roving (WR) fabric were used for the research, and epoxy resin was used in a stacking sequence of [CSM/0/90/CSM]2s. Other materials used in the research were as follows: The simulation carried out with ANSYS allowed for the determination of the stress, strain, deformation, force, and energy absorption, all of which were based on the outcome. Based on the simulation results for [CSM/0/90/CSM]2s, the energy recorded during the impact test is 0.282 J and the peak load of 738N. In bending test simulation, the bending stress for [CSM/0/90/CSM]2s is 633.43 MPa. In addition, more different test is recommended for future work.

Keywords: Marine Composite, Polymer Matrix Composite, Finite Element Analysis.

1. Introduction

When exposed to dangerous environmental conditions, marine structure such as boats, submersibles, and offshore projects are at risk due to unpredictable ocean conditions. Understanding the performance, capabilities, process characteristics, and sustainability of maritime applications in harsh climates has garnered focus.

Polymer Matrix Composite (PMC) is the most prevalent composite material. GFRP is made of polymer and glass fiber. Glass is the most used reinforcing fiber in composite construction, accounting for 90% of global consumption. It's strong, light, and affordable. When fiberglass is injected with epoxy

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resin, the resulting composite is twice as strong as steel per weight[1]. Most composite operations involve impact. It's important to study how composites react in different environments. Polymer matrix composites were tested with Charpy impact utilizing chopped strand mat (CSM), woven roving fabric (WR), and foam-PVC Klegecell as reinforcement with epoxy or polyester resin[2]. The study examined contact load, energy absorption, deflection, and damage behavior. Impact-tested every specimen to failure. Epoxy resin has a-greater impact-resistance than polyester resin.

For composite structure designers, static and fatigue strengths are the most essential material properties. When polymeric composites are exposed to tensile, flexural, or compressive pressures, they are susceptible to mechanical damage, which may lead to material failure[3]. The bending test provides more comprehensive information about the material's properties than the traditional tensile and compressive tests, therefore [4] explore sandwich composite of glass fiber, epoxy, and foam core by performing the three-point bending test. According to the study, there is a linear relationship between applied load and deflection, and the fracture on the bottom surface suggests that glass fiber is stronger in tension than in compression. Using a three-point bending test, the E-glass/epoxy composite's residual strength was determined [5]. The region of delamination affects the final strength of composite laminates. Multiple lateral delamination lowered the ultimate strength of laminated composites compared to multiple longitudinal delamination.

The marine environment makes choosing a structural material problematic. Long-term structural performance, durability, and sustainability need more study. Understanding the performance, characteristics, process capacities, and sustainability of maritime applications in harsh climates has attracted attention [9]. This study examines the durability of marine polymer matrix composites in impact and flexural using FEA.

2. Materials and Methods

2.1 Materials

For the purpose of this investigation, it was determined to make use of materials that are similar to those that can be discovered in marine boats in Malaysia. These materials are made up of chopped strand mat (CSM)/woven roving fabric (WR) as reinforcement and epoxy resin as the matrix[3]. Glass fibers of the CSM 450 and WR-300 variety were used, while epoxy resin of the ADR 246 TX kind was used as the matrix.

Table 1: Material properties of CSM/WR/Epoxy

Item	Chopped strand mat (CSM)	Woven roving fabric (WR)	Epoxy resin
Young modulus, E (GPa)	75	76	2.68
Poisson’s ratio	0.2	0.37	0.4
Density (kg/m^3)	2540	2551	1200

Composites were produced using a manual lay-up procedure that is comparable to the method used to construct GFRP (glass fiber reinforced plastic) boats, which are mostly used in the marine industries. The stacking layer of the composite structure is shown in Figure 1.

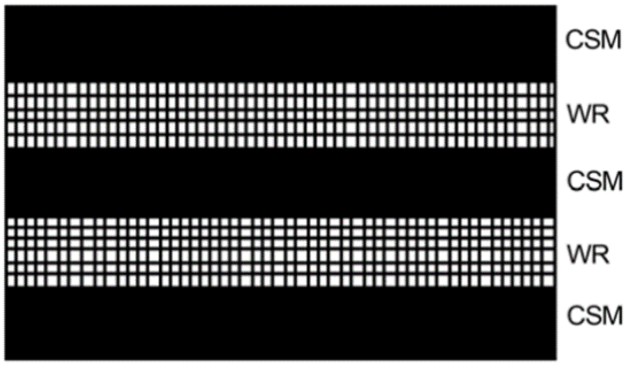

Figure 1: Layers of composite structure

Table 2: Material properties of CSM/WR/Epoxy

Type of resin	Epoxy
Layers	CSM – 3 WR -2
Stacking orientation	[CSM/0/90/CSM]2s
Average thickness	4 mm

2.2 Flowchart of FEA

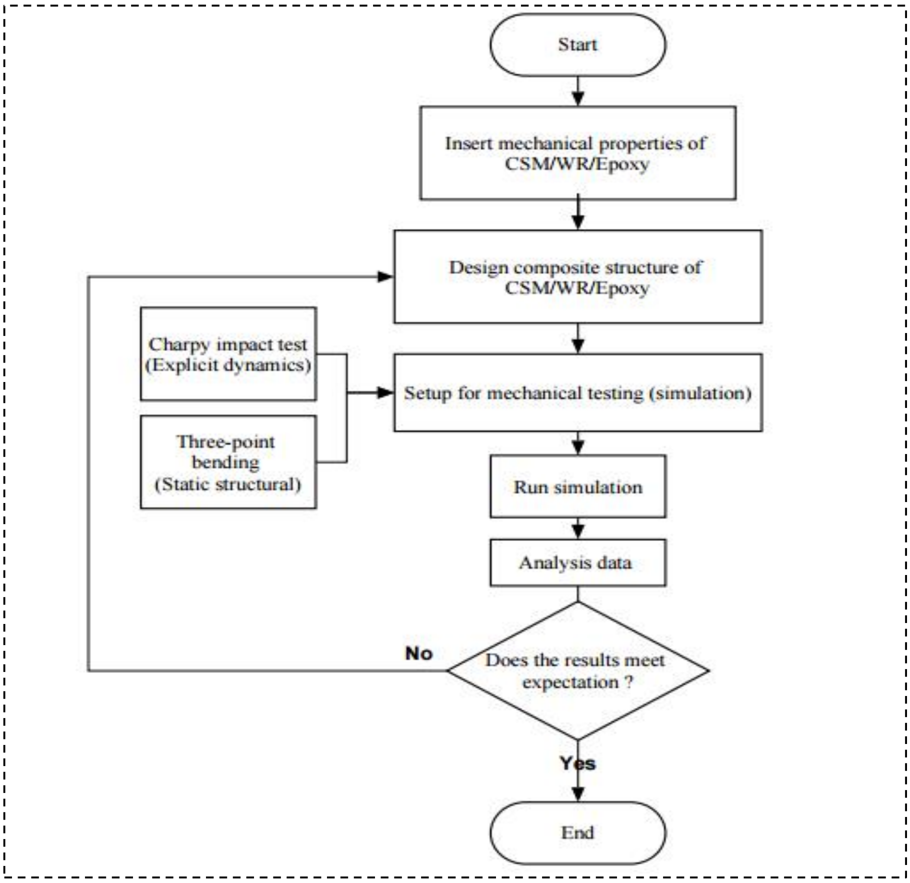

Figure 2: Flowchart of FEA

2.3 Charpy impact test

This study simulated Charpy Impact tests to identify marine composite structure impact behavior. The Charpy test is a dynamic three-point test in which the pendulum strikes the specimen in its center, producing kinetic energy. EN ISO 179-1 recommends a specimen size of 80 mm x 10 mm. The Charpy impact test device's finite element model includes a pendulum, support, and specimens. The pendulum's initial velocity was 3.85 m/s [1]. Figure 3 shows the flatwise Charpy impact test.

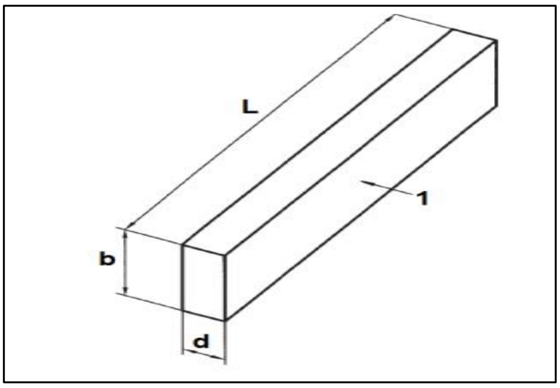

Figure 3: Flatwise Charpy impact test

2.4 Three-point bending test

Flexural testing involves a rectangular sample and three-point bending to evaluate specimen flexural response. This study used ANSYS Static Structural to perform a three-point bending test. The three-point bending test specimen is 80 mm long, 13 mm wide, and 4 mm thick according to ASTM D7264, a standard for producing and testing, as illustrated in Figure 4. In three-point bending modelling, existing research of comparable composite structures was used as reference. Y-direction loading rod displacement was 3.66mm. Experimental testing demonstrates that the greatest deflection to rupture of a comparable specimen composite construction. Cylindrical rods support and load the specimen. 10mm diameter rods.

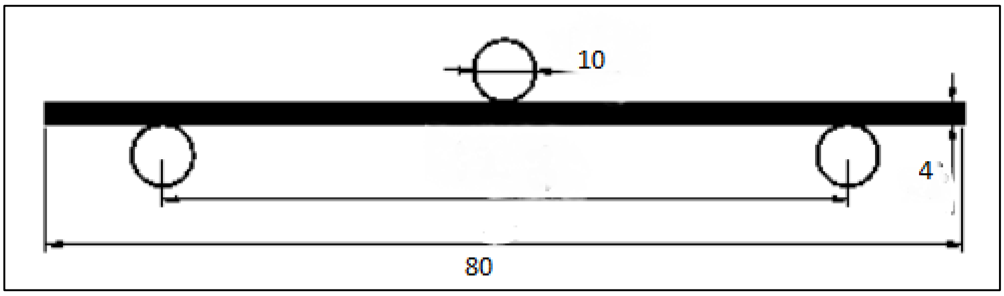

Figure 4: Three-point bending setup

2.5 ANSYS

Computer-Aided Product engineering includes design, simulated testing using complex analytical methods, and production planning. CAE is a product design and engineering process aid since it allows testing and simulations of a product's physical features without a prototype. FEM is a common CAE simulation analysis. In this work, ANSYS is used to design the composite structure as shown in figure 5.

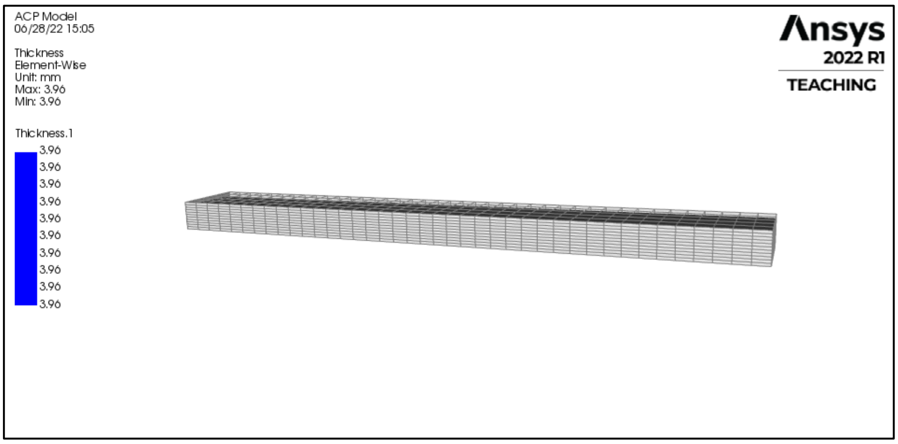

Figure 5: Composite structure designed in ANSYS

3. Results and Discussion

3.1 Charpy impact simulation

The pendulum, the support, and the specimens are the three components that make up the simulation model of the Charpy impact test equipment. A value of 3.85 meters per second was designated as the beginning velocity of the pendulum, while the specimen held in place at the beam support location. Results from simulation shows the deformation, stress, peak force and the energy from the impact situation. The maximum stress and deformation are located at the mid-span of the specimen since it is the area of impact as shown in Figure 6.

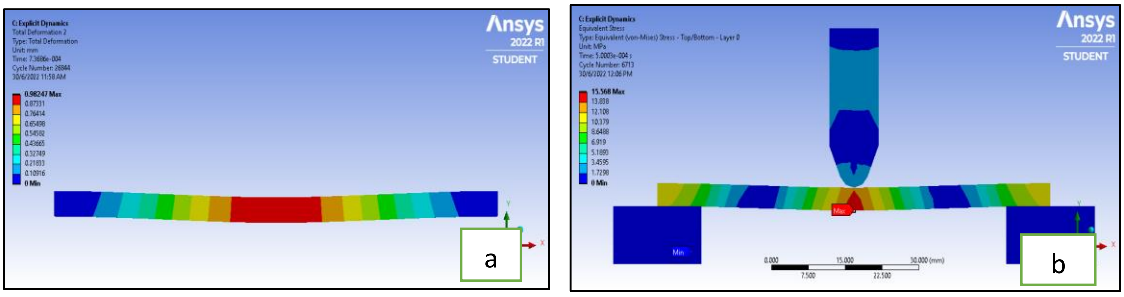

Figure 6 : (a) total deformation (b) Equivalent stress

The peak force and energy from the impact simulation were obtained and shows in Figure 7 and Figure 8. The highest load is 738 N, and the amount of energy recorded in the simulation is 0.282 J. This value is obtained when the pendulum hit the specimen. To compare the results, previous study of Charpy impact test on composite structure that was similar to this one, 0.6 J was found. The value obtained by the simulation have 72% difference with the previous study. Even though it has the same type of composite lamination structure, it acts differently. This is because the impact energy of a composite depends on how it is made and how long the fibres are, whether they are short or long[10].

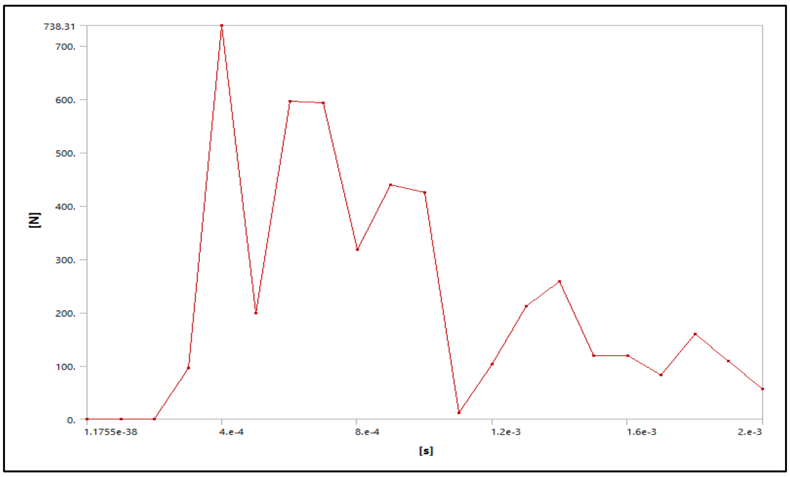

Figure 7: Force vs Time

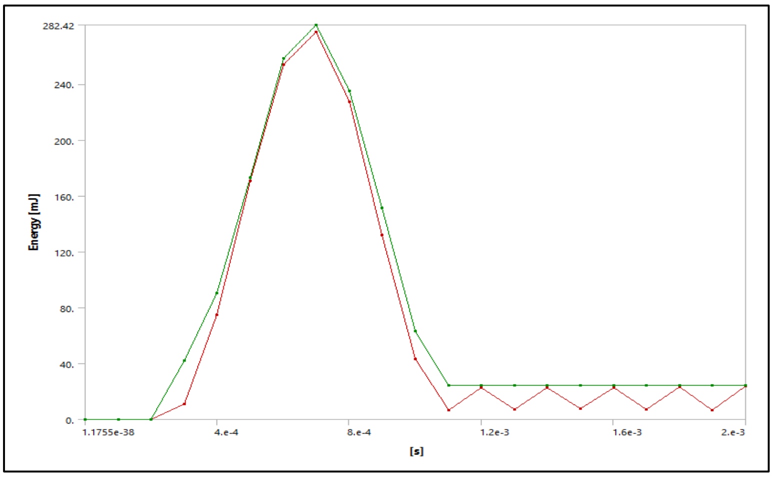

Figure 8: Energy Summary

3.2 Three-point bending

The bending behavior of an e-glass fiber epoxy composite was studied by plotting load-displacement and stress-strain curves. A 11538-node, 5772-element connection has been made. Figure 9 shows that the largest deformation occurs at the specimen's midspan, which is also the loaded area. In this investigation, 3.66 mm was used to model the specimen's greatest deflection to rupture. According to contour color grading, the midspan on both the top and bottom surfaces has a higher stress value. The span's peak compression and tensile stresses were also its highest bending stresses. Stress gauge. From the results, it shows a 633.43 MPa is the ultimate stress for the specimen in bending.

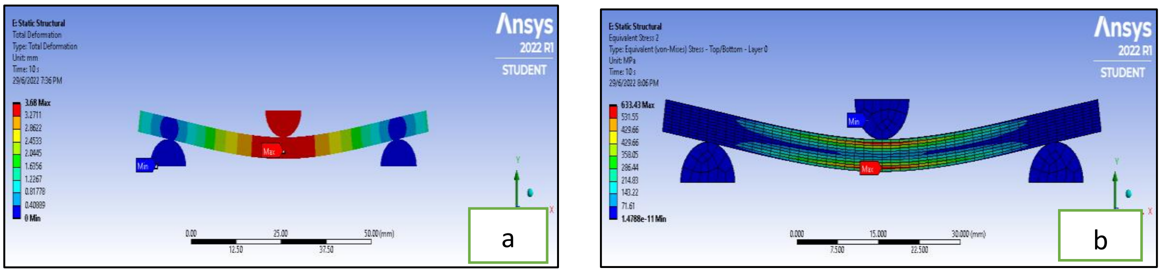

Figure 9: (a) deformation (b) equivalent stress

Figure 10 shows load vs deformation for three-point bending. When the rod pushes down on the specimen, 1.6175 kN of force are operating on it. Prior research of similar material in three-point bending showed 1.25 kN for the same displacement [11]. The maximum flexural stress for composite laminates increased in proportion to the strain rate during the test according the result in Figure 11. In addition, the flexural stress and strain both rise when the strain rates are increased, just as the research has shown [12].

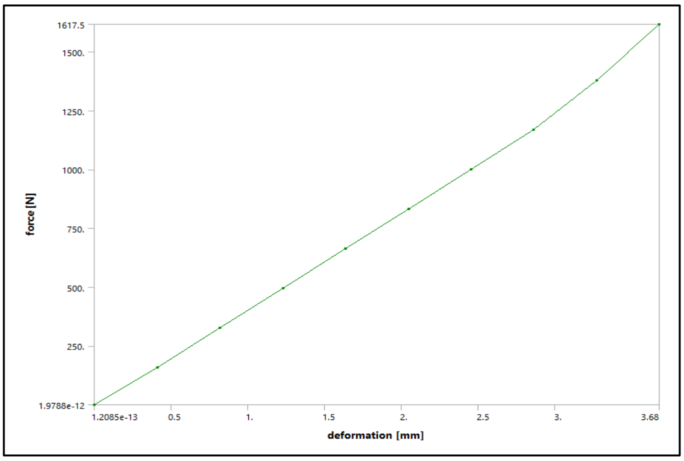

Figure 10 Load vs deformation

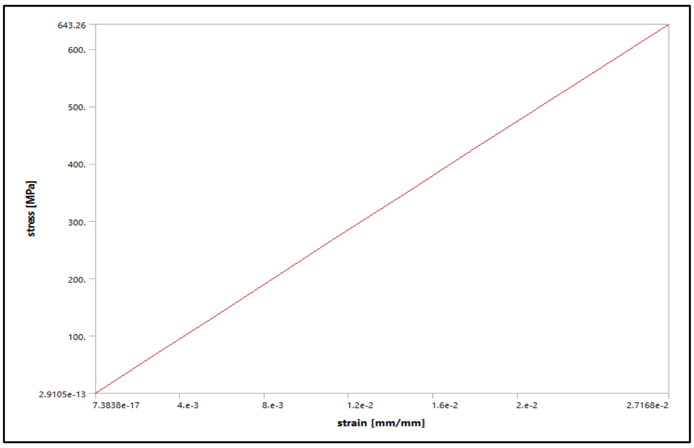

Figure 11: Stress-Strain

4. Conclusion

When operating in tough environmental circumstances, marine applications' performance, features, and process capabilities must be well understood. The impact Charpy test and static three-point bending test were simulated using ANSYS Workbench. The composite construction utilized in this study is common in maritime conditions and constructions and utilized components similar to those in Malaysian boats. The experiment used glass fiber and epoxy resin in [CSM/0/90/CSM]2s. Stress, strain, strength, and impact characteristics of this type of composite structures have also been identified. This study's goal was accomplished. This study aims to;

1 To identify the composite structure used in marine application.

2 To investigate the behaviour of composite structure [CSM/0/90/CSM]2_S based on impact and bending by using FEA.

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