International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 03 Issue: 04 April 2025
Page No: 1486 - 1492
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2025.0212

Life-Saving Wheelhouse

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Abstract

Safety of fishermen on fishing vessels is highly essential, particularly when navigating boats of up to 24 metres in length. This paper describes the concept design of a lifeboat, which is geared towards converting the control room (simply known as the "wheelhouse" in Tamil Nadu coastal regions) of a fishing vessel into a lifeboat capable of detaching in emergency situations. This research examines the concept to create the lifeboat for fishing vessels that are less than 24 m in length. This research begins with calculations, 3D design of the lifeboat, hydrodynamic and impact analysis and ends with choosing ideal material for the lifeboat. For the originally chosen carbon steel, calculations and simulation have been performed. The stability and buoyant force calculations showed that carbon steel, though structurally strong, has certain drawbacks that require new material to be developed. Therefore, a different material was invented to counter these setbacks. The new innovative material invented consisted of the integration of fibreglass, High-Density Polyethylene (HDPE), Expanded Polystyrene (EPS) granules and epoxy resin. This material is intended to be a lightweight, affordable solution with the required strength and buoyancy. The material underwent extensive mechanical testing, such as tension, bending and Charpy impact tests, to assess the properties of the material. The paper ends with a comprehensive comparison of the merits and demerits of the new material. This research will ultimately aim to enhance the safety and efficiency of life boat design in small fishing boats, improving the general reliability and survivability of the boat during emergency situations.

Keywords: *Life boat; GRP; Solid Works; Ansys; Composite Material.*

1. Introduction

Global aquaculture production, including aquatic plants, in 2018 was 114.5 million tonnes, with an estimated value of USD 263 billion. The Asia-Pacific region continued to be the major producer [1]. Fishing is one of the most perilous occupations, with maritime accidents posing significant risks to fishermen [2]. The global fishing fleet shrank by almost a tenth to 4.1 million vessels between 2015 and 2020 alone. Of these, only about 45,000 vessels were larger than 24 m; the majority (81 per cent) were small open boats less than 12 m in length, and this is one of the main causes of the safety problems in the fishing industry, especially since these small open boats are mainly operated in Asia and Africa [3]. Boats have a rich history, evolving in shape and purpose. From ancient log boats to modern superyachts, their design depends on their intended use [4]. A lifeboat is nothing but a lifesaving piece of equipment in ships used for emergency purposes [5]. A fishing boat typically works in remote locations away from the shore, and thus emergency preparedness is even more essential. In the case of an accident or tragedy, quick deployment of a lifeboat is very important to preserve lives. Designing lifeboats for fishing vessels less than 24 metres is particularly challenging. These ships are space- and weight-limited, and it is not easy to include life-saving technology that can withstand extreme marine conditions without being expensive and bulky. Safety regulations, such as those outlined by the International Maritime Organization (IMO), have emphasized the need for improved emergency

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preparedness, yet existing solutions remain inadequate for smaller vessels [6]. The first major interest in commercial FRP vessels was in the fishing industry. Today, approximately 50% of commercial fishing vessels are of FRP construction [7]. FRP is the main type of composite material which is extensively used in boat building [8]. The research follows a structured methodology, beginning with stability and hydrodynamic analysis of a lifeboat, followed by material selection based on structural performance, cost, and buoyancy [9]. Having considered these contents, this research aims to design the lifeboat for fishing boats less than 24 metres in length with the aim of having the control room of the boat be detachable from the rest of the boat in the event of an emergency. The project employs simulation software and material science to investigate novel design and material opportunities, progressing from a starting point of carbon steel design to a composite material structure with fibreglass and a polymer core. The final objective of this project is to develop a more cost- effective, lightweight, and budget-friendly lifeboat that can be used in times of emergency and also minimise the size of the lifeboat, making it more practical for smaller fishing vessels. [1-2]

2. Methodology

2.1.Design and Calculations

The lifeboat design was initially created with the aid of SolidWorks, wherein the control room was incorporated within the lifeboat structure to provide for separation during an emergency. The dimensions of the lifeboat are 3.3 metres in length, 2.4 metres in width, and 2 metres in height. The mass of the lifeboat is 2304.33 kg, and a further mass of 800 kg for 10 people (using 80 kg per person) and 400 kg for supplies and equipment, a total mass of 3505 kg or 34,384.05 N. The buoyant force acting on the boat is 35,904.6 N. This buoyant force is more than the total load of the boat, and therefore it allows the boat to float. The stability of the boat is also checked by finding the metacentric height (MH), i.e., the vertical distance between the centre of buoyancy (CB) and the centre of gravity (CG). MH (metacentric height), the metacentric height of the lifeboat is 0.06 m This value shows a stable boat design since the metacentric height in positive signifies that the boat will naturally come back to its position upright once it has been slightly tilted, assuring its stability. (Figure 1)

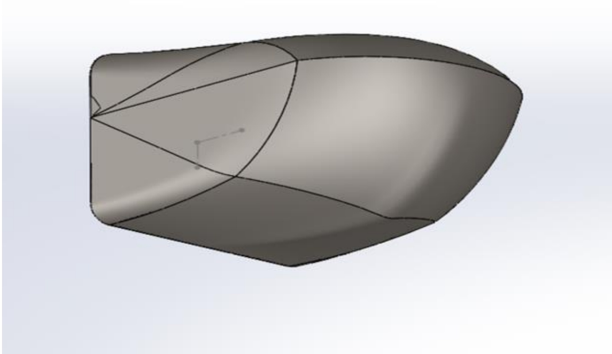

Figure 1 Life Boat 3D Model

2.1.1. Hydrodynamic Analysis

Throughout the simulation phase, the design of the lifeboat was simulated for different emergency situations, such as high-impact collisions in turbulent seas. Hydrodynamic simulations were employed to simulate the interaction of the lifeboat with water so that the boat would float and be stable in case of an emergency. These analyses helped determine key factors such as the required buoyant force and weight distribution to achieve optimal performance. These results indicate that stress increases with higher wave heights, demonstrating the material's stress vulnerability under increasingly harsh sea conditions. The boat's low metacentric height helped maintain stability in calmer waters (1 m to 3 m waves). (Figure 2,3,4,5)

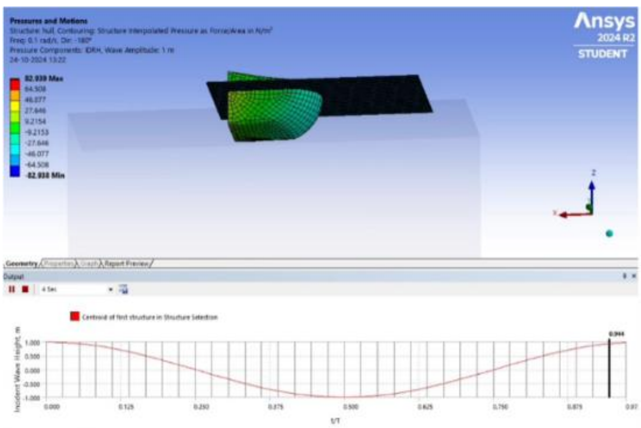

Figure 2 Wave Height – 1 m

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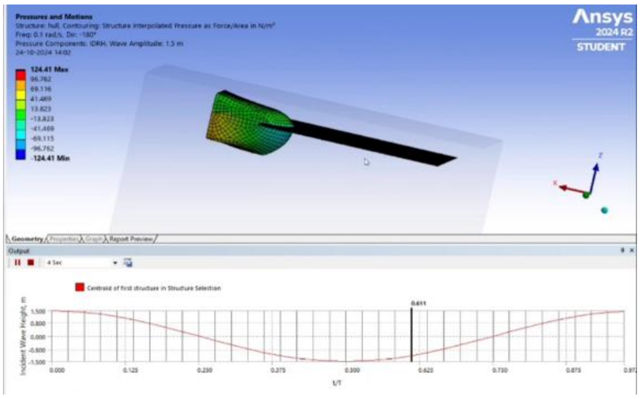

Figure 3 **Wave Height – 1.5 m**

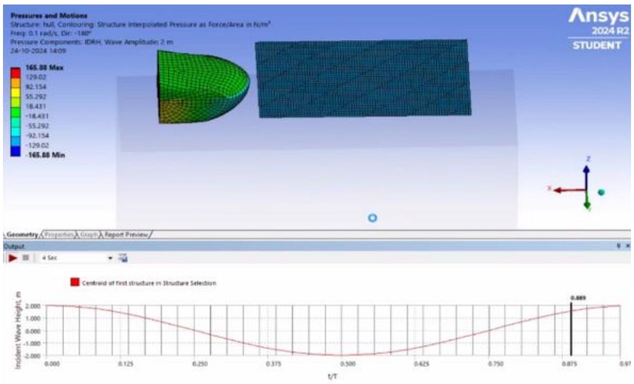

Figure 4 **Wave Height – 2 m**

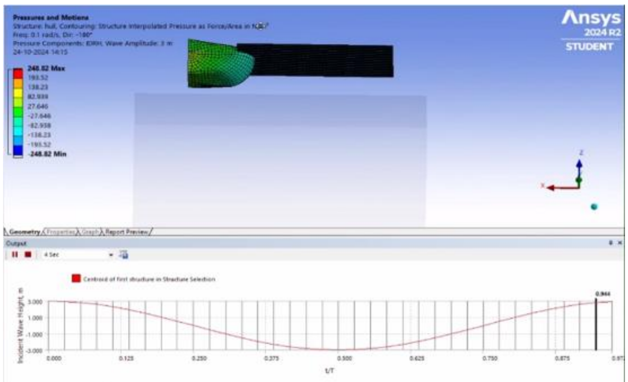

Figure 5 **Wave Height – 3 m**

- **1 m wave height:** maximum stress = 82.939 N/mm²
- **1.5 m wave height:** maximum stress = 124.41 N/mm²
- **2 m wave height:** maximum stress = 165.88 N/mm²
- **m wave height:** maximum stress = 248.82 N/mm²

2.1.2. Impact Analysis

The research emphasises impact where the lifeboat is dropped from 1.5 metres, which is moving vertically. And think about the detached lifeboat colliding in the corner of the boat. The simulation was done to know the transformations of the lifeboat, which was dropped from a height of 1.5 m, in consideration of freefall gravity (9.8 m/s²). (Figure 6) [5]

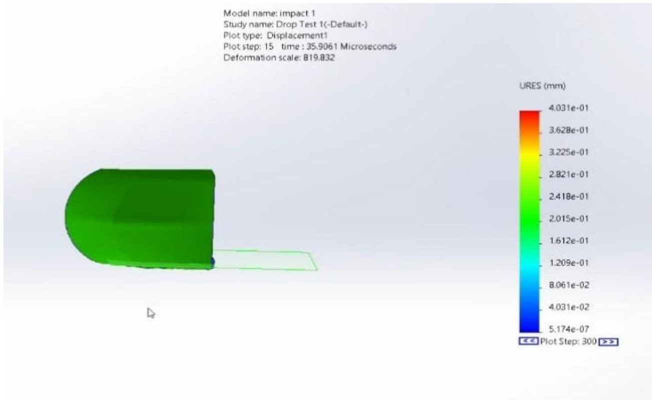

Figure 6 **Impact Test**

URES refers to resultant displacement, or the total of the magnitude of the overall displacement at a point. Results obtained from the simulation indicated a maximum value of 0.4031 mm, which shows the material's ability to withstand high stress without bursting. This suggests that carbon steel, despite its strength, undergoes very little change in shape under sudden forces, making it unable to maintain structural integrity in times of emergency. [3-4]

2.2.Failure of Carbon Steel

Carbon steel, however strong, could not be used in the lifeboat because of a combination of drawbacks regarding its weight, corrosion resistance, and ability to withstand impact. Perhaps the biggest flaw with carbon steel is that it is very dense, which contributes a significant amount of weight to the structure of the lifeboat. In the marine scenario, this surplus weight decreases the overall buoyancy of the boat, a safety and reliability critical parameter during emergency evacuation. Carbon steel is severely prone to corrosion when in contact with saltwater, a huge issue for any maritime use. The corrosion of the carbon steel would cause the structure of the lifeboat to deteriorate and decrease its lifespan, even to catastrophic failure in the case of an emergency. Such inadequacies identified the need for a material that was lighter in weight and corrosion-resistant but able to ensure buoyancy and structural integrity to the extent needed for an emergency lifeboat. [6]

3. Material Selection

3.1.GRP Considerations

As a solution to the limitations of carbon steel, Glass Reinforced Plastic (GRP) was also explored as a more feasible option. GRP is a composite material formed by mixing fibreglass with a resin matrix, having benefits in terms of weight, corrosion resistance, and mouldability and having high strength, durability, and buoyancy, hence being ideal for lifeboats and other marine use. Composite sandwich panels with FRP faces and low-density foam cores have become the best choice for small craft applications [10]. Glass fibre reinforced composite facings on PVC (polyvinyl chloride) foam cores are widely used sandwich materials in boat structures [11]. Although GRP offered a number of benefits, it was not without problems. One of the central problems was that it was very bulky, as a large quantity of GRP and foam material would be required to create the required buoyant force. This meant the amount of material would have a direct impact on cost and the total size of the lifeboat, and thus, it would not be practical for small fishing vessels. Additionally, the production cost of lifeboats made from GRP may be exorbitant, particularly when mass-producing for smaller boats. This led to the creation of a hybrid composite material with reduced cost and smaller size yet same advantages as GRP.

3.2.New Material Selection

The fibre-reinforced plastic composite components consist of fibre reinforcements (glass, carbon, aromatic polyamide fibres) embedded in resin (epoxy, polyester, phenol-formaldehyde). While the resin gives the composite its shape, surface appearance, environmental tolerance, and overall durability, the fibrous reinforcement bears most of the structural loads, thus primarily providing macroscopic stiffness and strength [12]. Composite sandwich structures have become particularly attractive for boat manufacturing, notably for high-performance racing boats where weight savings, material properties, and the possibility to be moulded into complex shapes are essential features to achieve superior performance [13]. To transcend the disadvantages of GRP, a novel hybrid composite material was created. This material comprised layers of fibreglass on either side, with an HDPE core and EPS granules as a core material, bonded together by epoxy resin. The composition constructed for the thickness of 10 mm in which there would be 2 mm of fibreglass sheets on each side and the middle portion would consist of a mixture of EPS and HDPE granules. The main goals for this work were to reduce volume and cost associated with GRP without compromising strength, buoyancy, and durability. Use of a foam core allows the material to stay buoyant without requiring huge amounts of material, resulting in a more compact and efficient design. [7]

4. Tests

In order to verify the efficiency of the new hybrid composite material, a series of mechanical tests were conducted. This research encompasses mechanical testing to evaluate the new material’s suitability, including tensile strength, bending resistance, and impact performance [14].

4.1.Tension Test

The tension test is a crucial mechanical property test to ascertain the strength and elongation characteristics of the materials under tensile loads. The test allows the evaluation of the material's suitability for use in structural parts of the lifeboat that will be subjected to various external forces and environmental factors. (Figure 7)

Figure 7 Tension Test

The stress-strain curve obtained from the test indicates the dependence of applied stress on the

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resulting strain when the material is loaded. The material has a linear zone where the stress varies linearly with strain, and it is elastic deformation. Once the material passes the yield point, it deforms plastically, which continues until failure. The graph also shows that the tensile strength of the material at failure is 1.4894 N/mm² and the elongation at break is 12.11%. This shows that the flexibility and impact resistance of the material are high, and thus it is crucial for saving lives. (Figure 8)

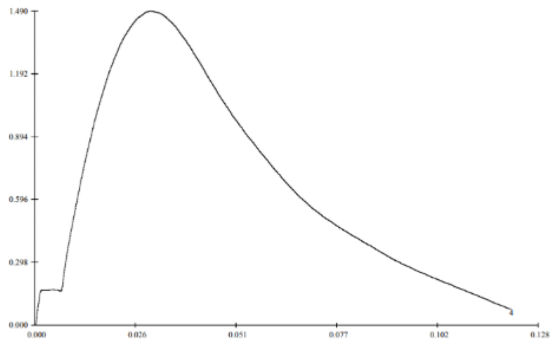

Figure 8 Stress Vs Strain Graph

4.2.Bending Test

Bending test was employed to examine the material flexibility and bending resistance when subjected to bending stresses. Bending test was conducted on a Universal Testing Machine (UTM) in order to load a simply supported beam in the middle. The applied load and associated deflection were recorded at regular intervals throughout the test. (Figure 9)

Figure 9 Bending Test

The highest load imposed on the sample was 21.8540 N, producing a deflection of 28.2498 mm. The strain at this time was 28.2498%, and the material showed a flexural strength of 0.0312 N/mm². The results clearly show that the material cannot sustain large deformation under bending loads. (Figure 10)

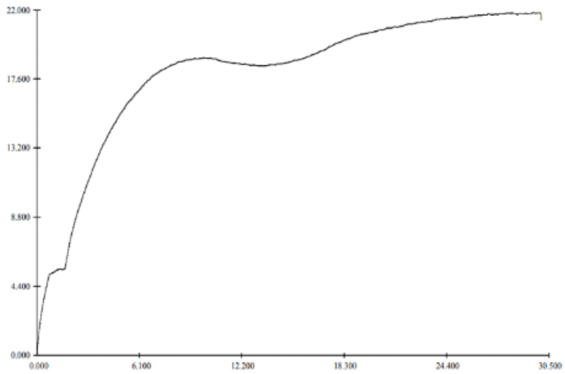

Figure 10 Load Vs Displacement Graph

4.3.Charpy Impact Test

This test was used to determine the resistance of the material to impact and sudden shock. The impact energy of the composite manufactured material was determined by finding the amount of energy prior to its fracture. The test specimen used was 55 mm in length, 10 mm in width, and 10 mm in thickness. The impact energy absorbed by the material is 2.64 J, and the impact stress calculated was 0.044 J/mm². (Figure 11)

Figure 11Charpy Impact Test

The newly created composite material for use in lifeboat construction did not fully break in the Charpy impact test, a factor that can be contributed to by many factors. The composite material made of layers of fibreglass with an HDPE and EPS granules core is

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tough and flexible. These properties make it possible for the material to be able to withstand large amounts of impact energy without failure. [8-10]

5. Results and Discussion

5.1.Comparison with GRP

Glass Reinforced Plastic (GRP) has been a first-choice material for lifeboat construction for decades due to its extremely high strength-to-weight ratio and excellent durability. GRP, as a composite material made of glass fibres reinforced in a resin matrix, is more impact-resistant, corrosion-resistant, and flexible. But it also possesses some drawbacks, namely its fairly high cost and weight. In comparison, the new material in the form of fibreglass layers with an HDPE and EPS granule core, epoxide resin bound, provides a lighter weight, lower-cost alternative with similar strength. The new composite material, with its multi-layered design, reduces the material's overall thickness, reduces weight, and increases manufacturing convenience. Despite the fact that GRP offers maximum corrosion resistance, the new material further guarantees, added with HDPE and EPS granules, increased toughness and buoyancy. Compared under the aspect of mechanical performance, GRP also possesses increased durability, impact resistance, and overall structural strength, particularly in hostile marine conditions. GRP's resistance to corrosion and long life when subjected to seawater conditions are well established, whereas the new material, although promising, may be an issue regarding long-term strength and the potential for material degradation with time. The new composite material also suffers from issues regarding impact and fatigue resistance, especially in comparison to the high-performance qualities of GRP. Tests revealed that while the new material had a low performance in impact and tension tests, it was likely to be of durable long-term duration because of EPS and HDPE granules. The lighter weight, lower-profile new composite material is more buoyant than traditional GRP and easier to handle and stow on under 24-metre fishing vessels. Production is made cheap in comparison to GRP by using HDPE and EPS granules as the core. This allows it to be mass-produced at a low cost for small fishing vessels. The combination of fibreglass layers with core materials provides a flexible yet robust structure. The addition of EPS granules enhances environmental wear resistance, while impact and UV degradation protection is provided by the fibreglass layers. [11]

Table 1 Comparison Between GRP and New Material

Properties	GRP	New Material
Tensile stress (MPa)	28.2 - 78.8	1.4894
Flexural strength (MPa)	44.6 -119.2	0.0312
Impact Strength (J)	3.50 - 6.50	2.64
Density (g/cm^3)	1.41	1.025

5.2.Future Prospects

Incorporating corrosion inhibiting additives or protective coatings within the fibreglass can increase its lifespan in marine environments. Firm epoxy resin treatments can be developed from the material to render it saltwater-resistant, and the lifeboat's lifespan would be increased. Try out with different types of foam material or incorporating a hybrid core, such as the combination [12] of EPS with other floatable materials such as polyurethane or EPP (expanded polypropylene), might further optimize buoyancy and minimize weight even further. These foam types might offer enhanced toughness and energy absorption properties upon impacts. By including high-tech hybrid composites, such as carbon fibre layers or aramid fibres (e.g., Kevlar) between the fibreglass, the material can be further optimized to better absorb high-speed impacts and sudden shocks, providing it with more strength against outside forces. A promising future area of development is optimising the thickness of the material and the fibreglass content ratio. By doubling the thickness of the fibreglass layer to 30 mm, the performance of the material in impact resistance, tensile strength, and durability could also be dramatically enhanced, arguably making the material similar to GRP in general structural integrity. Also, using recyclable or environmentally friendly resins could give the material another edge, addressing environmental issues and helping to further the eco-credentials of the lifeboat, which is especially vital in the contemporary boat-building industry. [13-14]

Conclusions

The new hybrid composite material performed poorly as compared to carbon steel in many major areas, such as tensile strength and impact resistance. The material also performed well as compared to GRP, especially with regard to cost and size effectiveness. The material performance is poor primarily due to a small quantity of fibreglass mat; if more materials of the fibreglass mat are added, it will raise the overall performance. These encouraging results showed that this new composite material would be an acceptable substitute to use in constructing lifeboats. Generally, the process of design and materials selection of lifeboats on fishing vessels under 24 metres featured carbon steel, which, though structurally strong, was extremely hard to utilize owing to the challenges of weight, corrosion protection, and all-round performance. The transition to GRP gave huge weight and corrosion advantages but was limited by the material's great volume and cost. A new hybrid composite material, fusing fibreglass with HDPE and EPS granules, provides a breakthrough solution to these limitations by minimizing size and cost without sacrificing the required strength and buoyancy. There has been extensive testing that has proved the superiority of this new material, and it is a clear candidate for use in future lifeboats. The study adds to the safety and efficiency of life-saving appliances for small fishing vessels, providing additional protection for crew members in the case of an emergency. [15]

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