Design And Analysis of Glass Fibre Material of a Crane Hook for Structural Stability

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Abstract— ***The project aims at the design and manufacturing of a crane hook using glass fiber composite material, with the primary objective of reducing weight without compromising its load-bearing capacity. Conventional crane hooks, usually made of steel, are heavy and prone to corrosion, which affects efficiency and handling. In this work, topology optimization is employed to minimize the material volume of the hook while maintaining the required breaking load capacity. The existing crane hook design is first analyzed to determine structural stresses under loading conditions. Finite Element Analysis (FEA) is then carried out on the optimized design using suitable software to evaluate stress distribution, deformation, and safety factor. Glass fiber composite is selected for manufacturing due to its high strength-to-weight ratio, corrosion resistance, and cost-effectiveness. The optimized composite hook is fabricated through appropriate composite processing techniques, and its mechanical performance is validated experimentally. The ultimate breaking load of the prototype is tested on a Universal Testing Machine (UTM) and compared with the performance of conventional steel hooks. The results demonstrate that glass fiber composite can serve as a lightweight alternative material for crane hooks while maintaining structural reliability, thereby improving operational efficiency, safety, and sustainability in lifting applications.***

Keywords— Crane Hook, Composite material, UTM.

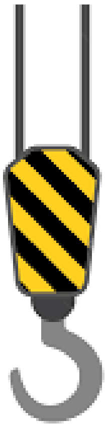
I.INTRODUCTION

Cranes play a critical role in industrial lifting operations, and the crane hook is one of their most vital load–carrying components, responsible for safely transferring loads during hoisting and material-handling processes. Traditionally, crane hooks are manufactured from high-strength steel alloys due to their excellent load-bearing capacity and ductility. However, these metallic hooks possess inherent limitations including high self-weight, susceptibility to corrosion, and increased manufacturing and maintenance costs. As industries move toward lighter, more energy-efficient, and durable lifting equipment, the need for alternative materials and optimized structural designs has become increasingly important. The global shift toward lightweight components in overhead cranes, mobile cranes, and construction machinery further highlights the importance of reducing the mass of load-bearing elements without compromising safety or performance.

In recent years, material innovation and computational design tools have opened new possibilities for structural components traditionally dominated by metals. Advanced fiber-reinforced composite materials—especially glass fiber composites—have gained significant attention due to their high strength-to-weight ratio, corrosion resistance, tailorability, and cost-effectiveness. Studies on composite structural elements have shown their potential to replace metallic components in numerous engineering applications, yet their use in highly loaded crane hooks remains relatively unexplored. While steel hooks provide proven strength, their weight increases system inertia, energy consumption, and operator fatigue, especially in applications requiring repetitive lifting. This gap presents an opportunity to investigate the feasibility of lightweight composite crane hooks that can improve operational efficiency and sustainability.

Furthermore, geometric refinement through computational design techniques has become a crucial pathway for improving structural strength while reducing material usage. Topology optimization, widely used in aerospace, automotive, and biomechanical engineering, provides the ability to redesign components with minimal mass while maintaining or enhancing structural integrity.

Coupling topology optimization with the Finite Element Method (FEM) allows engineers to predict stress distribution, deformation behavior, and failure tendencies under complex loading scenarios. For components such as crane hooks—where stress concentration, bending, and shear effects are significant—FEA-driven optimization offers a scientific basis for achieving both safety and weight reduction.



Given this context, the present work explores the design and analysis of a crane hook made from glass fiber composite material, focusing on achieving structural stability while significantly reducing weight. The study begins with the analysis of an existing steel crane hook to determine the baseline stress behavior under operational loads. Topology optimization is then applied to minimize material volume without affecting the required breaking load capacity. The optimized model is evaluated through detailed finite element simulations to examine stress distribution, deformation response, and safety factors. Following the numerical analysis, a glass fiber composite hook is fabricated using suitable composite manufacturing techniques, and its performance is validated experimentally using a Universal Testing Machine (UTM). Finally, the mechanical performance of the composite hook is compared with that of a conventional steel hook to assess improvements in weight, load capacity, and overall structural reliability.

II.LITERATURE REVIEW

1. Dipu et al. (2024)

Dipu et al. investigate crane hook design using finite element analysis and programming-based automation to identify an optimal cross-section. They emphasize the high stress concentration in hooks due to their curved geometry and highlight limitations of conventional forged-steel designs. Their simulations compare various cross-sections to determine which provides the most uniform stress distribution and lowest peak stresses. Automated modelling helps conduct multiple iterations efficiently and reduces human error. Results show that optimized geometries improve safety and enable lighter hook designs. The authors conclude that their approach can be applied to other curved load-bearing components.

2. Hiep et al. (2024)

Hiep et al. apply size and topology optimization to redesign a crane hook for significant weight reduction without compromising mechanical performance. Using ABS plastic as the test material, they integrate Python-based GEKKO optimization, CAD tools, and 3D printing to create multiple variants. The optimized Type-F hook achieves a high safety factor with reduced mass. Additional topology optimization removes unnecessary material, reducing weight by up to 70% while maintaining safe stress limits. Experimental compression tests validate the simulation findings. The study demonstrates the strong potential of combining computational optimization with additive manufacturing for lightweight hook design.

3. Kishore et al. (2020)

Kishore et al. analyze the failure of a 24-tonne crane hook using metallurgical examination, fractography, curved-beam theory, and FEA. The failed hook, after 18 years in service, exhibited fatigue striations and beach marks confirming high-cycle fatigue failure. Microscopic observations revealed non-metallic inclusions and machining marks that acted as stress concentrators. Analytical and FEA results showed the highest stresses at the threaded region where fracture initiated. Introducing simulated notches increased stress values significantly, reinforcing the role of surface defects. The study recommends higher steel purity, improved machining, and periodic inspection for safer long-term operation.

4. Wibawa (2024)

Wibawa evaluates the static and fatigue performance of an Al-6061-T6 crane hook under loads from 5 to 10 tons. Static analysis shows that stresses and deformation rise with increasing load but stay below the material’s yield strength. Fatigue life, however, decreases drastically at high load levels, dropping below one million cycles at 10 tons. This establishes fatigue as the critical design factor for aluminum crane hooks. While aluminum offers benefits such as low weight and corrosion resistance, it demands conservative design margins at higher loads. The study emphasizes the need to integrate fatigue criteria when selecting lightweight materials.

5. Mereuta (2024)
Mereuta compares crane hooks of different cross-sectional geometries and materials using 3D CAD modelling and finite element analysis. Two steels—AISI 1020 and high-strength 34CrMo4—are analyzed under identical loading conditions. Both materials remain within safe limits, but 34CrMo4 provides substantially higher safety factors. Stress concentrations consistently appear at the inner curvature of the hook, matching earlier research. The study shows that geometric optimization can significantly improve stress distribution. It concludes that selecting the proper cross-section and material combination is essential for enhancing hook performance.

6. Xie et al. (2025)
Xie et al. examine hybrid GFRP-reinforced concrete slabs to evaluate their flexural behavior and load-carrying capacity. They combine glass fiber bars with concrete to address corrosion issues faced by steel reinforcement. Experimental tests reveal improved crack resistance and enhanced ductility in hybrid slabs. Finite element simulations accurately reflect experimental load–deflection behavior. Results show that GFRP reinforcement effectively improves structural performance while reducing long-term durability concerns. The study supports wider adoption of hybrid composite reinforcement in civil infrastructure.

7. Hassan et al. (2025)
Hassan et al. explore blast-resistant composite panels using heterogeneous fiber distribution and zoning optimization. They divide the panel into regions with varying fiber orientations and properties to improve energy absorption. Numerical simulations show that zoning significantly reduces front-face deflection and back-face damage under blast loading. Experiments confirm that optimized panels withstand higher blast energy compared to uniformly reinforced ones. The design improves stiffness, damping, and failure control through tailored fiber placement. The work demonstrates the value of material zoning for high-performance protective structures.

8. Wu et al. (2025)
Wu et al. study the design and testing of GFRP pressure vessels for applications requiring corrosion-resistant lightweight containers. They use filament winding with optimized fiber angles to achieve improved burst strength. Finite element analysis predicts stress patterns and validates the structural behavior under internal pressure. Experimental hydrostatic testing confirms that the composite vessel meets design requirements. The study shows excellent agreement between simulation and testing. The authors highlight GFRP's advantages over metallic vessels in terms of weight, durability, and cost.

9. Sirswey et al. (2022)
Sirswey et al. analyze fatigue failure tendencies in crane hooks with different geometries and materials. They use finite element analysis to determine stress concentration zones under cyclic loading conditions. Results show that certain profiles reduce stress intensity and delay crack initiation. Material comparisons reveal that higher-strength alloys provide better fatigue resistance. The authors recommend profile optimization alongside material selection for improved working life. Their findings help guide safer and more durable crane hook designs.

10. Ashuro et al. (2024)
Ashuro et al. evaluate hybrid glass–sisal fiber reinforced polyester composites to determine how natural fibers can enhance mechanical properties. Tensile, flexural, and impact tests reveal that hybridization improves overall strength and stiffness. Increasing glass fiber proportion leads to significant mechanical improvement, while sisal contributes to cost reduction and sustainability. Failure analysis shows improved bonding when optimal fiber ratios are used. The study demonstrates that hybrid composites can achieve a balance between performance and eco-friendliness. These materials are suitable for lightweight structural applications.
Novelty of work: The novelty of this study lies in the development of a lightweight crane hook using glass fiber composite material, replacing conventional heavy steel hooks while ensuring equivalent structural strength. Unlike previous studies that focus solely on geometric optimization or material characterization, this work uniquely integrates topology optimization, finite element-based validation, composite manufacturing, and full-scale

experimental testing into a single workflow. The research demonstrates, for the first time, a practically manufacturable topology-optimized crane hook fabricated from GFRP, bridging the gap between simulation-driven lightweight design and real-world load testing. Additionally, the work provides a direct experimental comparison between the optimized composite hook and a conventional steel hook to quantify improvements in weight reduction, structural stability, corrosion resistance, and breaking load performance. This combined computational–experimental approach establishes a new pathway for adopting composite materials in high-load lifting components, where such applications are still largely unexplored.

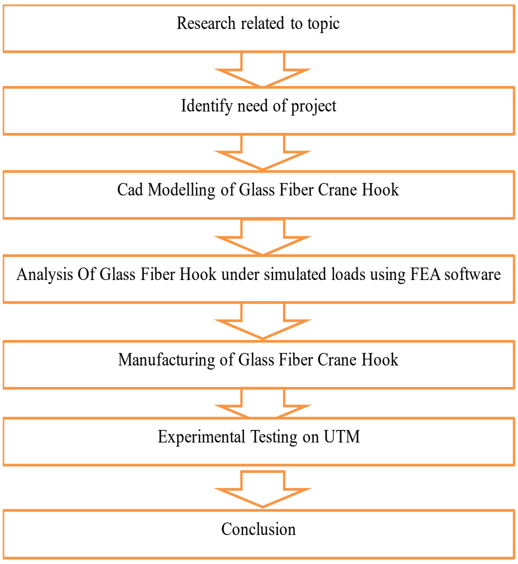
III.PROBLEM STATEMENT

- Traditionally, crane hooks are manufactured from metals such as steel due to their high strength and durability. However, metallic hooks are heavy. Excessive weight leads to higher energy consumption during lifting and can contribute to fatigue failure in the crane system over prolonged use.
- The complex geometry of a hook, combined with the anisotropic nature of composites, makes it difficult to predict stress distribution and failure points accurately.
- Moreover, ensuring that a lightweight composite hook can achieve the required breaking load without compromising safety is a significant concern.
- This project focuses on addressing these challenges by analyzing the structural performance of conventional crane hook designs, applying topology optimization and understanding the mechanical behavior of glass fiber composites in a hook geometry, to reduce weight while maintaining strength.

IV.OBJECTIVES

- To reduce the weight without compromising strength (breaking load) material by using topology optimization.
- To find structural stresses of existing crane hook design.
- To find structural stresses of hook using suitable FEA software and try to reduce the weight of crane hook.
- To study composite material strength and its utilization for crane hook design.
- To test the ultimate breaking load of optimized composite crane hook on Universal Testing Machine.

RESEARCH METHODOLOGY



V.FINITE ELEMENT ANALYSIS

Finite Element Analysis (FEA) is a numerical method used to analyze and predict the behavior of engineering structures under various loading and boundary conditions. It is based on the principle of discretizing a complex geometry into a finite number of smaller elements, known as a mesh. Each element is connected through nodes, and the governing equations of mechanics are applied to these elements to approximate the overall response of the structure. This approach enables the analysis of complex shapes and loading conditions that are difficult to solve using classical analytical methods.

The fundamental concept of FEA is derived from continuum mechanics, where the behavior of a structure is governed by equations of equilibrium, compatibility, and material constitutive relations. By applying these equations to each element and assembling them into a global system, the method computes unknown variables such as displacement. From these primary results, secondary parameters like stress, strain, and deformation can be obtained.

In structural analysis, loads and boundary conditions are applied to the finite element model, and the system of equations is solved to determine the response of the structure. The accuracy of the results depends on factors such as mesh quality, element type, and material properties. Finer meshes generally provide more accurate results but require higher computational effort.

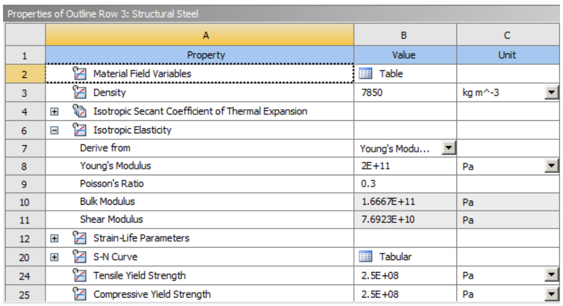
FEA is widely used in engineering design to evaluate performance, identify critical stress regions, and optimize structures before physical prototyping. In this study, FEA is employed to analyze the crane hook under loading conditions, enabling the assessment of deformation, stress distribution, and structural stability for different materials and geometries.

FEA of Existing Crane Hook:

Geometry:

Fig. Geometry of Existing Crane Hook.

Material Properties:

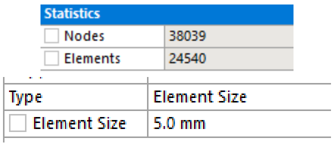


Properties of Outline Row 3: Structural Steel

	A	B	C
1	Property	Value	Unit
2	Material Field Variables	Table	
3	Density	7850	kg m^-3
4	Isotropic Secant Coefficient of Thermal Expansion		
6	Isotropic Elasticity		
7	Derive from	Young's Modu...	
8	Young's Modulus	2E+11	Pa
9	Poisson's Ratio	0.3	
10	Bulk Modulus	1.6667E+11	Pa
11	Shear Modulus	7.6923E+10	Pa
12	Strain-Life Parameters		
20	S-N Curve	Tabular	
24	Tensile Yield Strength	2.5E+08	Pa
25	Compressive Yield Strength	2.5E+08	Pa

Fig. Material Properties of Steel.

Meshing:



Statistics	
Nodes	38039
Elements	24540

Type	Element Size
Element Size	5.0 mm

Fig. Meshing Details of the existing crane hook.

Boundary Conditions:

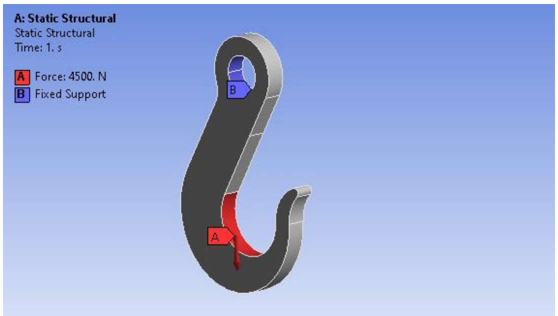


Fig. Boundary Conditions for the static structural analysis of the existing crane hook.

Results

Total deformation

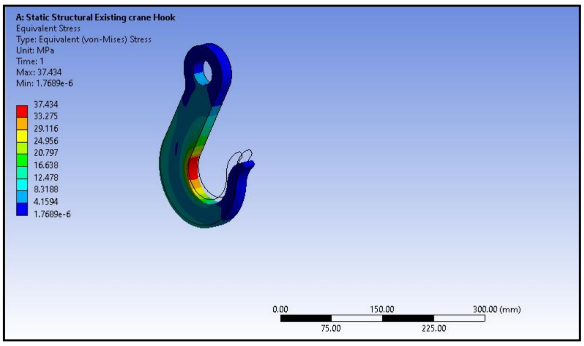


Fig: Total deformation plot for existing crane hook

Equivalent Stress

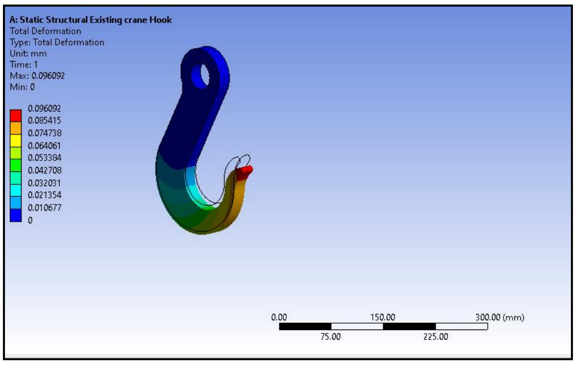


Fig: Von Misses Stress plot for existing crane hook

Equivalent Elastic strain

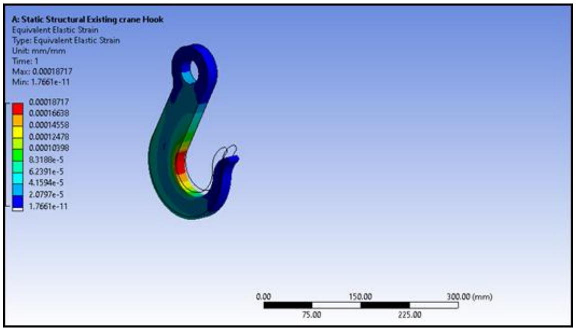


Fig: Equivalent Elastic strain plot for existing crane hook

Topology Optimization:

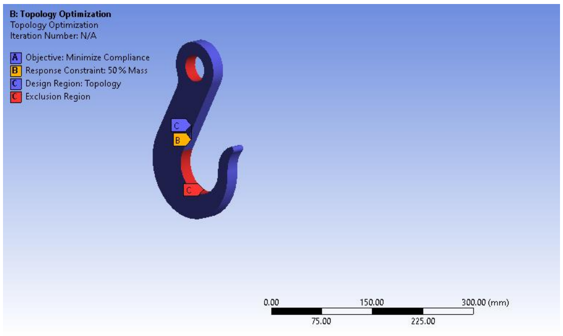
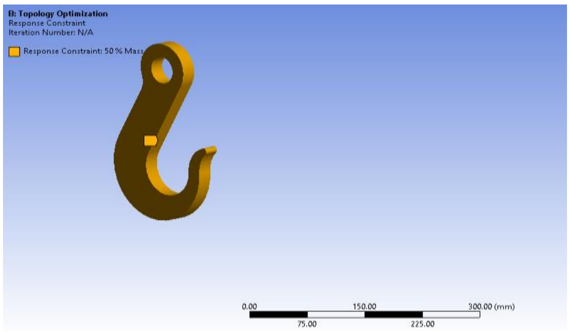
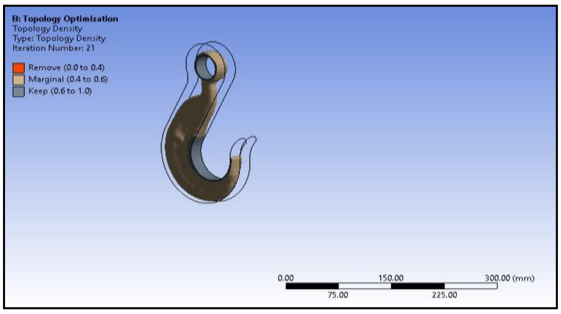


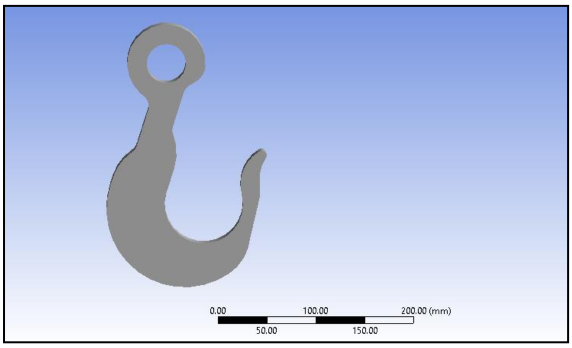
Fig: Boundary condition for topology optimization

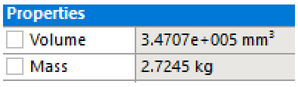




FEA OF NEW OPTIMIZED MODEL

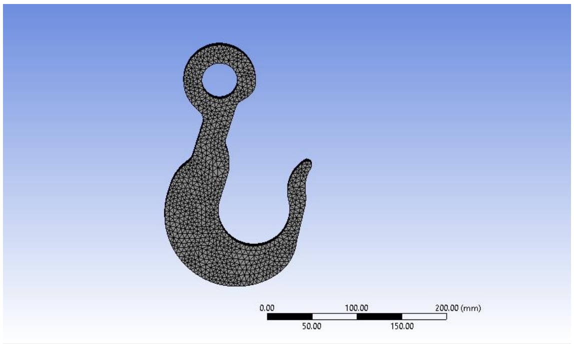
Geometry

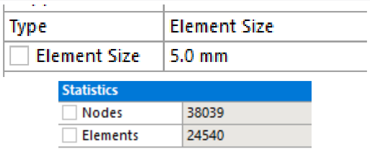




Properties	
☐ Volume	3.4707e+005 mm^3
☐ Mass	2.7245 kg

Meshing





Type	Element Size
☐ Element Size	5.0 mm

Statistics	
☐ Nodes	38039
☐ Elements	24540

Fig. Meshing Details of Optimized Crane Hook.

Boundary condition

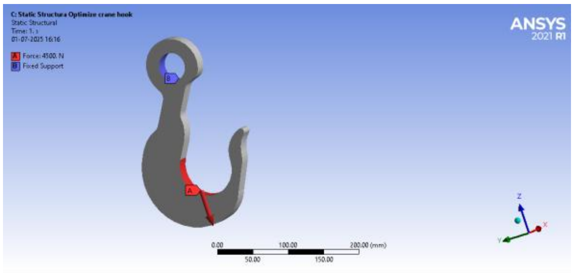


Fig. boundary conditions for static structural analysis of the Optimized crane hook.

Results

Total Deformation

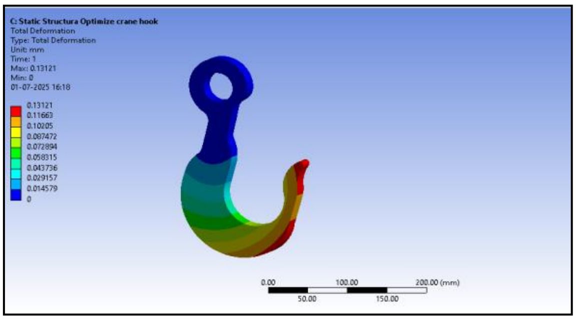


Fig. Total Deformation of Optimize crane hook.

Equivalent Stress

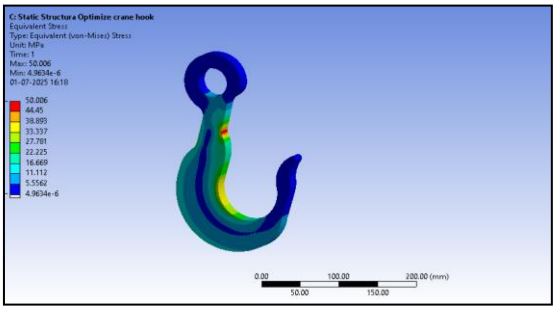


Fig. Equivalent Stress of Optimize crane hook

Equivalent Elastic strain

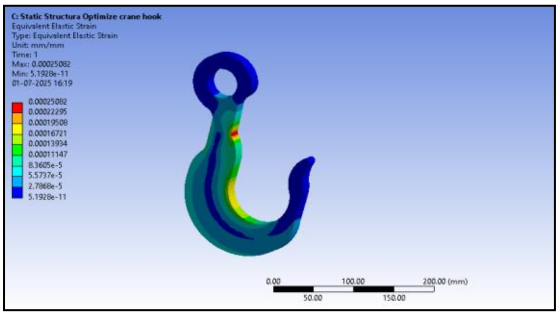


Fig. Equivalent Elastic strain of Optimize crane hook

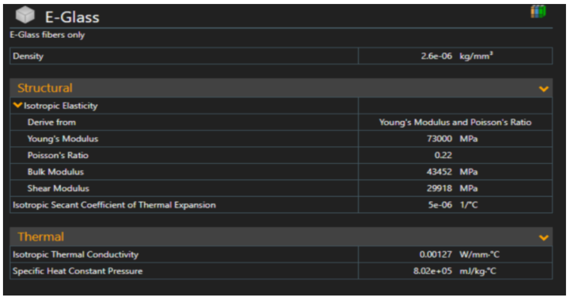
FEA of Glass Fiber Crane Hook:

Geometry

☐ Volume	3.4707e+005 mm³
☐ Mass	0.90239 kg

Fig. Geometry of Glass Fiber Crane Hook.

Material Properties:



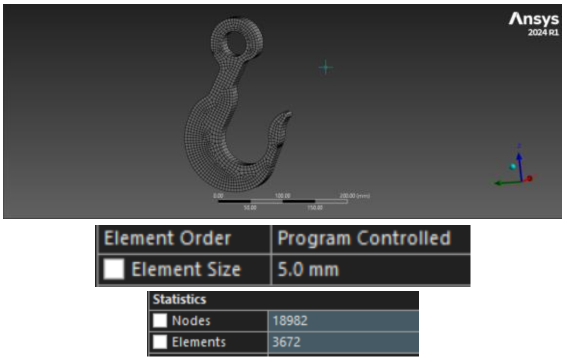
E-Glass

E-Glass fibers only

Density	2.6e-06 kg/mm³
Structural	
Isotropic Elasticity	
Derive from	Young's Modulus and Poisson's Ratio
Young's Modulus	73000 MPa
Poisson's Ratio	0.22
Bulk Modulus	43452 MPa
Shear Modulus	29918 MPa
Isotropic Secant Coefficient of Thermal Expansion	5e-06 1/°C
Thermal	
Isotropic Thermal Conductivity	0.00127 W/mm·°C
Specific Heat Constant Pressure	8.02e+05 mJ/kg·°C

Fig. Material Properties of Glass Fiber

Meshing



Element Order	Program Controlled
☐ Element Size	5.0 mm

Statistics	
☐ Nodes	18982
☐ Elements	3672

Fig. Meshing Details of Glass Fiber Crane Hook.

Boundary condition

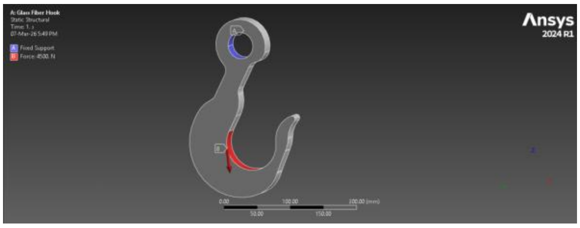


Fig. boundary conditions for static structural analysis of Glass Fiber Crane Hook.

Results

Total Deformation

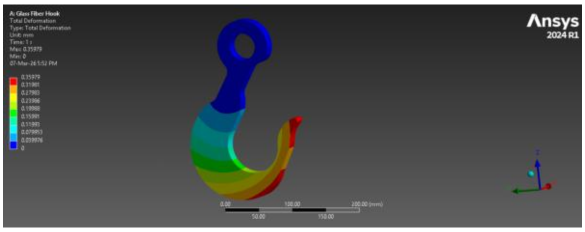


Fig. Total Deformation of Glass Fiber Crane Hook.

Equivalent Stress

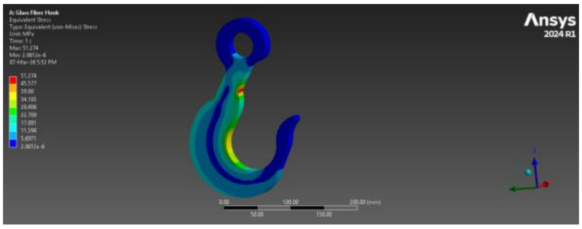


Fig. Equivalent Stress of Glass Fiber Crane Hook.

Equivalent Elastic strain

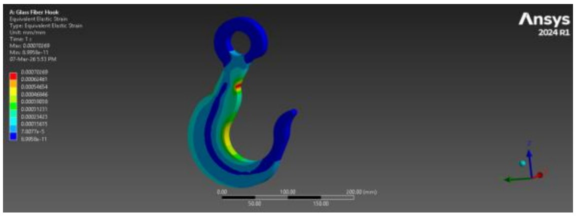
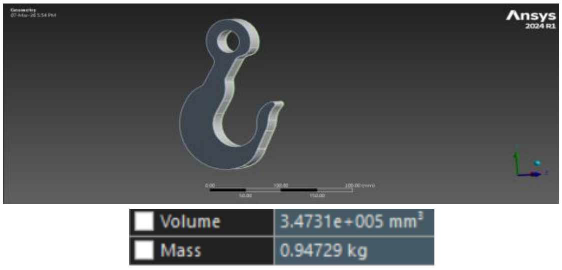


Fig. Equivalent Elastic strain of Glass Fiber Crane Hook.

FEA of Aluminium glass Fiber reinforced Crane Hook.:

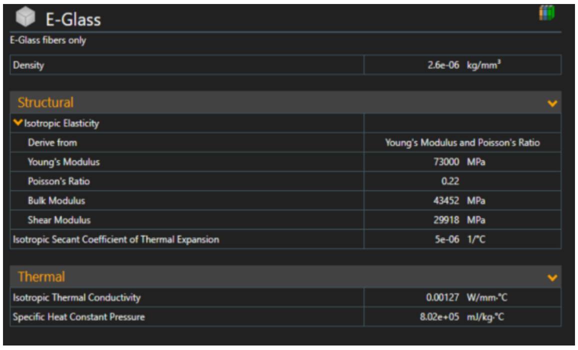
Geometry



☐ Volume	3.4731e+005 mm³
☐ Mass	0.94729 kg

Fig. Geometry of Aluminum Glass Fiber reinforced Crane Hook.

Material Properties:

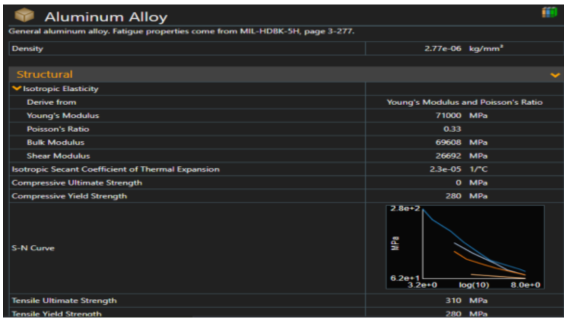


E-Glass

E-Glass fibers only

Density	2.6e-06 kg/mm³
Structural	
Isotropic Elasticity	
Derive from	Young's Modulus and Poisson's Ratio
Young's Modulus	73000 MPa
Poisson's Ratio	0.22
Bulk Modulus	43452 MPa
Shear Modulus	29918 MPa
Isotropic Secant Coefficient of Thermal Expansion	5e-06 1/°C
Thermal	
Isotropic Thermal Conductivity	0.00127 W/mm·°C
Specific Heat Constant Pressure	8.02e+05 mJ/kg·°C

Fig. Material Properties of Glass Fiber.



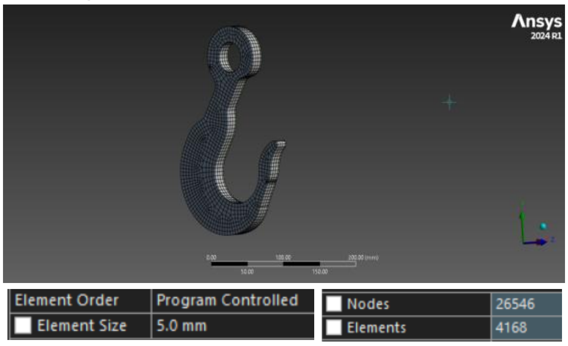
Aluminum Alloy

General aluminum alloy. Fatigue properties come from MIL-HDBK-5H, page 3-277.

Density	2.77e-06 kg/mm³
Structural	
Isotropic Elasticity	
Derive from	Young's Modulus and Poisson's Ratio
Young's Modulus	71000 MPa
Poisson's Ratio	0.33
Bulk Modulus	69608 MPa
Shear Modulus	26692 MPa
Isotropic Secant Coefficient of Thermal Expansion	2.3e-05 1/°C
Compressive Ultimate Strength	0 MPa
Compressive Yield Strength	280 MPa
S-N Curve	
Tensile Ultimate Strength	310 MPa
Tensile Yield Strength	280 MPa

Fig. Material Properties of Aluminium Alloy.

Meshing



Element Order	Program Controlled	☐ Nodes	26546
☐ Element Size	5.0 mm	☐ Elements	4168

Fig. Meshing Details of Aluminium glass Fiber reinforced Crane Hook.

Boundary conditions

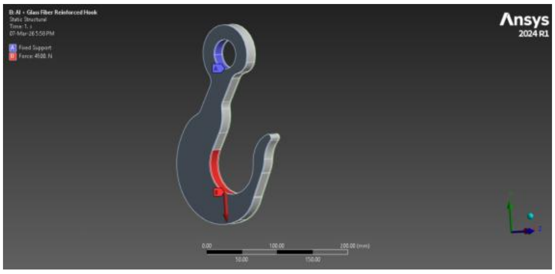


Fig. boundary conditions for static structural analysis of Aluminium glass Fiber reinforced Crane Hook.

Results

Total Deformation

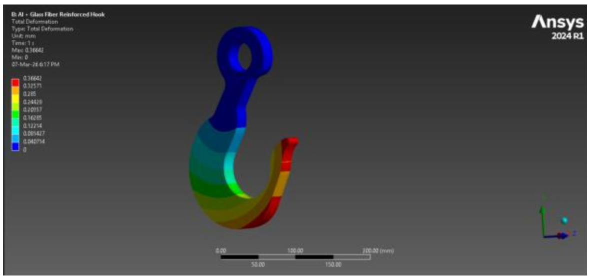


Fig. Total Deformation of Aluminum glass Fiber reinforced Crane Hook.

Equivalent Stress

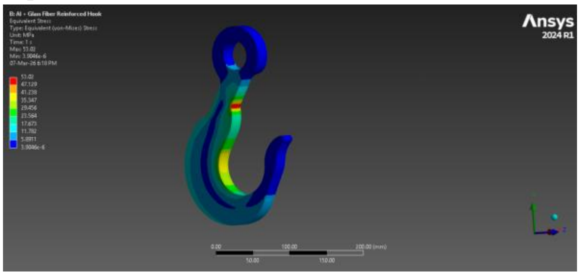


Fig. Equivalent Stress of Aluminum glass Fiber reinforced Crane Hook.

Equivalent Elastic strain

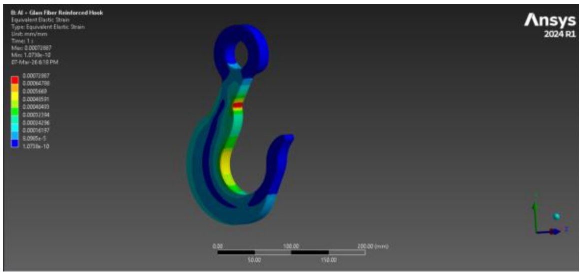


Fig. Equivalent Elastic strain of Aluminum glass Fiber reinforced Crane Hook.

FEA RESULTS

Finite Element Analysis (FEA) was carried out using ANSYS to evaluate the structural behavior of the crane hook under identical loading and boundary conditions. The analysis was performed on four configurations: the existing steel hook, the topology-optimized steel design, the optimized design with glass fiber composite material, and the aluminium core glass fiber reinforced (GFR) hook. The performance was assessed in terms of total deformation, equivalent (von Mises) stress, and equivalent elastic strain.

The existing steel crane hook exhibited a maximum total deformation of 0.096092 mm, an equivalent stress of 37.434 MPa, and an equivalent elastic strain of 0.00018717. These results indicate that the conventional design has high stiffness and maintains minimal deformation under the applied load.

After applying topology optimization, the redesigned steel hook showed a maximum deformation of 0.13121 mm, an equivalent stress of 50.006 MPa, and an equivalent elastic strain of 0.00025082. The increase in deformation and stress is attributed to material removal; however, the values remain within safe limits, confirming that the optimized design retains adequate structural strength.

The optimized geometry was further analyzed using glass fiber composite material. The results showed a maximum deformation of 0.35979 mm, an equivalent stress of 51.274 MPa, and an equivalent elastic strain of 0.00070269. Although the deformation increased due to the lower modulus of elasticity of the composite material, the stress levels remained within permissible limits, indicating its suitability for load-bearing applications.

Finally, the aluminium core glass fiber reinforced crane hook demonstrated a maximum deformation of 0.36642 mm, an equivalent stress of 53.02 MPa, and an equivalent elastic strain of 0.00072887. This hybrid configuration exhibited performance comparable to the pure composite model, with slightly higher stress and deformation values but still within acceptable limits.

Overall, the FEA results indicate that the optimized and composite-based crane hook designs can achieve satisfactory structural performance while enabling significant weight reduction compared to the conventional steel hook.

V.MANUFACTURING OF THE COMPONENT

The scaled-down crane hook prototype was initially fabricated from aluminium using the waterjet cutting process. This method was selected due to its high cutting precision, ability to produce complex geometries, and the absence of heat-affected zones, thereby preventing thermal distortion of the material. The aluminium plate was cut according to the optimized CAD profile to obtain the base hook geometry.

Fig. Aluminium crane hook prototype after waterjet cutting.

After fabrication, the aluminium hook was cleaned and its surface was slightly roughened to improve adhesion with the composite material. This surface preparation step is essential to ensure proper bonding between the metal substrate and the reinforcement layer.

Fig. Reinforcement of glass fiber composite using Resin solution.

The reinforcement was carried out using glass fiber composite with a suitable resin solution through the hand lay-up process. Layers of glass fiber were carefully applied over the aluminium hook, and resin was uniformly spread to ensure proper impregnation of the fibers. The layered structure was then left to cure at room temperature for sufficient time to achieve the desired mechanical strength.

Once curing was completed, the specimen was trimmed to remove excess material and finished to obtain a smooth and uniform surface. The final product was a hybrid aluminium core glass fiber reinforced crane hook, ready for experimental testing.

VI.EXPERIMENTAL TESTING

A Universal Testing Machine (UTM) is a mechanical testing device used to determine the strength and deformation characteristics of materials under various types of loading such as tension, compression, and bending. It operates by applying a controlled load to a specimen while measuring the corresponding displacement or deformation. The main components of a UTM include a load frame, movable crosshead, load cell, and data acquisition system.

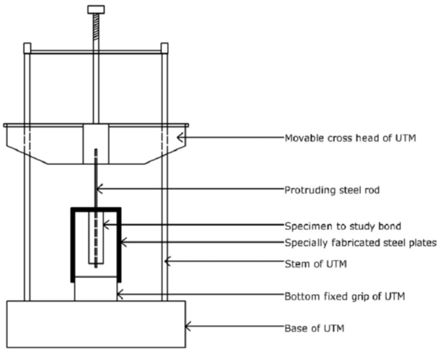


Fig. Components of UTM.

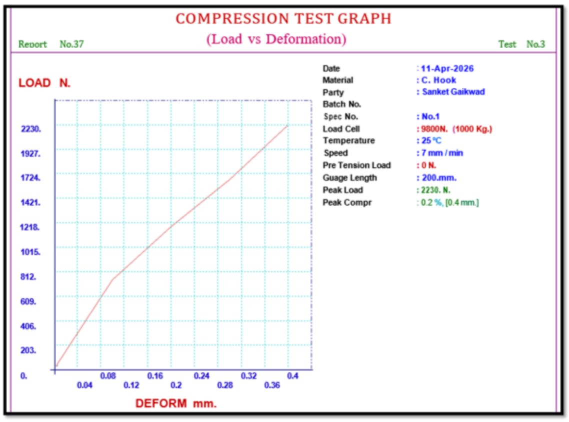
The specimen was tested using a Universal Testing Machine to evaluate its load-carrying capacity. A compression test was performed to simulate the loading conditions experienced by the hook during actual lifting operations.

Before testing, the specimen was visually inspected to ensure proper curing of the composite layer and absence of defects. The hook was then positioned between the compression plates of the UTM, ensuring proper alignment so that the load was applied at the critical region of the hook. Care was taken to avoid any misalignment that could introduce errors in the results.

The load was applied gradually and continuously, and the corresponding deformation was recorded throughout the test. The test was continued until the specimen reached its maximum load-carrying capacity or showed signs of failure such as excessive deformation or cracking.

Fig. Specimen under compression test using UTM.

Testing Graph:



Date	: 11-Apr-2026
Material	: C. Hook
Party	: Sanket Gaikwad
Batch No.	
Spec No.	: No.1
Load Cell	: 9800N. (1000 Kg.)
Temperature	: 25 °C
Speed	: 7 mm / min
Pre Tension Load	: 0 N.
Guage Length	: 200.mm.
Peak Load	: 2230. N.
Peak Compr	: 0.2 %, [0.4 mm.]

Fig. shows Compression test graph.

The above graph shows the results of the compression test performed on the Specimen. The Y-axis shows Load in Newton, and the X-axis shows deformation in mm.

FEA of Prototype for Experimental testing:

Boundary Conditions:

Fig. Boundary conditions for Static Structural Analysis of the GFR Al Hook prototype.

Results:

Total Deformation:

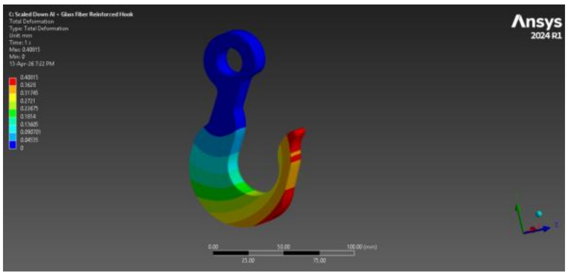


Fig. Total deformation of the hook prototype.

The experimental results were compared with the FEA results, and a close agreement was observed between them. This validates the accuracy of the numerical analysis and confirms that the aluminium core glass fiber reinforced crane hook can safely withstand the applied loads while offering a lightweight alternative to conventional steel hooks.

Conclusion

- The present study focused on the design, analysis, manufacturing, and experimental validation of an innovative crane hook using glass fiber composite material with an aluminium core.
- The results demonstrate that topology optimization effectively reduces material usage while maintaining the structural integrity of the crane hook. Although the optimized geometry exhibited slightly higher deformation and stress compared to the conventional steel design, the values remained within acceptable limits, confirming its structural reliability.
- The use of glass fiber composite significantly contributed to weight reduction while maintaining adequate load-bearing capacity. Despite a higher deformation due to lower stiffness, the stress levels were within safe limits, indicating that composite materials can be successfully used in lifting applications. The hybrid configuration with an aluminium core further improved the structural performance by providing better load distribution and support to the composite layers.
- The manufacturing of the prototype using waterjet cutting and hand lay-up techniques proved to be effective and practical. Experimental testing using a Universal Testing Machine validated the FEA results, showing good agreement between numerical and experimental outcomes. This confirms the accuracy of the simulation approach and the feasibility of the proposed design.
- Overall, the study establishes that aluminium core glass fiber reinforced crane hooks can serve as a lightweight, corrosion-resistant, and structurally reliable alternative to conventional steel hooks.
- The integration of topology optimization, advanced materials, and experimental validation highlights a promising approach for improving efficiency, safety, and sustainability in lifting equipment. Future work may focus on fatigue analysis, large-scale testing, and the use of advanced composite materials to further enhance performance.

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