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## DESIGN AND ANALYSIS OF REINFORCED COMPOSITE BRACKETS TO ENHANCE STRUCTURAL INTEGRITY IN MATERIAL HANDLING OVERHEAD CRANE

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## ABSTRACT

This research focuses on the design and analysis of reinforced composite brackets used in overhead cranes for industrial material handling, aimed at improving structural integrity, load-bearing capacity, and overall crane performance. The demand for enhanced durability and efficiency in material handling systems necessitates a shift towards innovative materials that offer superior strength-to-weight ratios and resilience under dynamic loading conditions. This study investigates the structural properties of brackets made from reinforced composite materials, comparing them with conventional metal brackets commonly used in overhead cranes.

The methodology involves computational modeling and finite element analysis (FEA) to evaluate the stress distribution, deformation, and failure modes of the reinforced composite brackets under various loading conditions representative of real-world industrial applications. Composite materials, due to their customizable properties, are optimized to improve stiffness, reduce weight, and mitigate stress concentrations within the bracket design. This analysis incorporates variations in fiber orientation, reinforcement type, and matrix material to determine the optimal configuration for structural performance and longevity.

**Keywords:** Finite Element Analysis, Structural analysis, Material optimization comparative analysis, Material handling crane.

## 1. INTRODUCTION

This study aims to design and analyze reinforced composite brackets specifically for use in overhead cranes, evaluating their structural integrity, performance under load, and potential advantages over conventional metal brackets. Using computational modeling and finite element analysis (FEA), we investigate the stress distribution, deformation patterns, and failure thresholds of various composite configurations. By optimizing the fiber orientation, reinforcement type, and composite layering, the study seeks to identify a bracket design that maximizes strength while minimizing weight.

The findings of this research have implications for the design of more efficient, durable, and safer material handling systems. Through the integration of advanced composite materials, this study demonstrates the potential for significant improvements in industrial crane performance, reduced energy consumption, and decreased maintenance requirements. This research contributes to the ongoing exploration of composite applications in heavy-duty industrial settings, paving the way for innovative solutions that address both functional demands and sustainability goals in material handling technology.

In industrial material handling, overhead cranes are essential for efficiently transporting heavy loads within facilities such as warehouses, manufacturing plants, and construction sites. A critical component of these cranes is the support bracket, which bears significant stresses and loads, often leading to wear, deformation, and eventual failure over time. Traditionally, these brackets are constructed from metals, which, while robust, add considerable weight to the system, increasing the energy demand and limiting flexibility in design. The high weight and susceptibility to corrosion of metal brackets also lead to frequent maintenance, elevated operational costs, and potential safety risks in demanding industrial environments.

In recent years, advancements in materials engineering have led to the development of reinforced composite materials, offering a promising alternative due to their superior strength-to-weight ratio, corrosion resistance, and customizable mechanical properties. Composites, which combine different materials such as fibers and polymer matrices, can be engineered to exhibit high tensile strength, enhanced stiffness, and improved fatigue resistance, making them ideal for structural applications under dynamic loading conditions. The use of reinforced composite brackets in overhead cranes has the potential to reduce overall system weight, improve load-bearing capacity, and extend the service life of the crane.



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#### **OBJECTIVES**

- To design reinforced composite brackets for overhead cranes that enhance structural integrity and load-bearing capacity compared to conventional metal brackets.
- To conduct finite element analysis (FEA) on composite brackets to evaluate their performance under various loading conditions, including stress distribution, deformation, and failure modes.
- > To identify the optimal composite material configuration by exploring different fiber orientations, reinforcement types, and matrix materials that maximize strength-to-weight ratio and durability.
- To compare the structural performance of composite and traditional metal brackets, focusing on weight reduction, fatigue resistance, and overall efficiency in industrial material handling applications.
- To analyze the impact of composite bracket implementation on operational factors such as energy consumption, maintenance requirements, and safety in overhead crane operations.
- > To provide recommendations for integrating composite materials into overhead crane design to improve efficiency, reduce costs, and extend the service life of material handling equipment in industrial settings.

## 2. METHODOLOGY

#### a) Literature Review and Material Selection

Conduct a comprehensive literature review on composite materials commonly used in structural applications, focusing on those with high strength-to-weight ratios and favorable mechanical properties for industrial environments. Select suitable fiber reinforcements (e.g., carbon fiber, glass fiber) and matrix materials (e.g., epoxy, polyester) that offer high load-bearing capacity, impact resistance, and fatigue durability.

#### b) Design and Modeling of Composite Brackets

Using CAD software, develop initial bracket designs based on existing metal bracket geometries, adjusting dimensions to account for the material properties of composites. Design variations are created to explore different fiber orientations, reinforcement distributions, and layer thicknesses to optimize the bracket's structural performance.

#### c) Finite Element Analysis (FEA) Setup

Import CAD models into FEA software (e.g., ANSYS, ABAQUS) to simulate and analyze the structural behavior of composite brackets under various loading conditions. Define boundary conditions and apply load cases that replicate typical operational stresses experienced by brackets in overhead crane systems, such as tensile, compressive, and bending forces.

#### d) Evaluation of Mechanical Performance

Perform FEA on each composite bracket configuration, analyzing key performance metrics including:

Stress distribution: Assess how the bracket distributes loads across its structure.

Deformation: Measure deformation levels to evaluate rigidity and resistance to bending.

**Failure modes**: Identify potential points of material failure or excessive deformation, particularly under cyclic loading conditions.

Fatigue analysis: Simulate repeated loading to assess long-term durability and estimate the lifespan of each bracket design.

#### e) Comparison with Conventional Metal Brackets

For benchmark comparison, model and analyze the performance of conventional metal brackets under the same loading conditions. Compare results to determine the relative advantages in weight reduction, stress resistance, and fatigue life offered by composite materials.

#### f) Optimization of Composite Design

Based on FEA results, optimize the composite bracket design by adjusting fiber orientation, reinforcement type, and layer thickness to enhance performance. Iteratively refine designs to achieve a bracket configuration that balances weight, strength, and durability, aiming for a marked improvement over metal brackets.

#### g) Experimental Validation

If resources allow, fabricate a prototype of the optimized composite bracket and conduct physical load testing to validate FEA predictions. Experimental testing could include tensile tests, compression tests, and cyclic fatigue tests to confirm the model's accuracy and practical feasibility.

#### h) Data Analysis and Interpretation

Analyze FEA and experimental results to determine the effectiveness of the composite bracket design in improving overhead crane performance. Interpret findings in terms of weight reduction, structural integrity, and operational efficiency, and assess potential impacts on energy savings, maintenance needs, and safety.



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## 3. CONCLUSION AND RECOMMENDATIONS

Summarize key findings, highlighting the benefits and potential limitations of using composite materials for crane brackets. Provide recommendations for integrating reinforced composite brackets in industrial crane applications, emphasizing implications for efficiency, sustainability, and cost-effectiveness.

## 4. EXPERIMENTAL RESULTS AND DISCUSSIONS

This experimental procedure outlines the steps for fabricating and testing reinforced composite brackets intended to enhance the structural integrity of material handling overhead cranes. The aim is to validate the computational analysis and confirm the performance improvements offered by composite materials.

## 1. Material Selection and Preparation

**A. Select suitable reinforcements matrix materials** based on desired mechanical properties such as high strength-to-weight ratio, fatigue resistance, and durability.

Prepare the selected composite materials, ensuring fibers are oriented according to the optimal configuration identified in the design phase

## **B.** Composite Bracket Fabrication

Fabricate the composite bracket prototypes using a suitable manufacturing process such as:

Build up the composite structure in a mold.

Cure the composite according to resin specifications (temperature, time) to achieve optimal bonding and mechanical properties.

After curing, demold the composite bracket and perform post-processing (e.g., trimming, surface finishing) as needed.

## C. Bracket Mounting and Setup for Testing

Mount the fabricated composite bracket on a test rig designed to simulate the load-bearing conditions of an overhead crane. Ensure the bracket is securely fixed and aligned in a way that replicates the actual operational environment, including support points, load angles, and constraints.

## **D. Static Load Testing**

Apply static load gradually to simulate operational forces the bracket would experience in an overhead crane setting.

Use a load frame or hydraulic press to apply controlled loads while measuring key metrics:

Stress and Strain Measurement: Attach strain gauges to monitor the strain distribution across critical points.

Deformation Monitoring: Use dial gauges or digital displacement sensors to measure deflection and deformation.

Record the load at which any visible signs of material yielding or deformation appear.

## E. Fatigue Testing

Set up cyclic loading equipment to test the bracket's fatigue resistance by repeatedly applying a load representative of operational conditions. Define loading cycles and frequency to simulate long-term usage in overhead crane applications. Measure and record deformation and any signs of fatigue damage (e.g., microcracking, delamination) at regular intervals. Continue cyclic loading until failure occurs or until reaching the targeted number of cycles (e.g., 1 million cycles) to determine the fatigue life.

## F. Data Collection and Analysis

Collect data from all testing phases, including load-deformation curves, stress-strain profiles, fatigue life.

Compare experimental results with the predictions from finite element analysis (FEA) to validate computational models. Analyze discrepancies, if any, and determine the accuracy and reliability of the FEA model.

## 4.1 Result Summary (From Experimental & Finite Element Analysis)

A specimen of LM 25 Alloy +Sic material is made for UTM test. Density & Modulus of elasticity of that material is determined by these tests to use these values in FEM analysis. FEM results are validated experimentally using UTM. Following steps are followed for experimental validation.

Sr. No	Description	Deformation	Stress analysis
1	Experimental	0.071	230
2	Finite Element Analysis	0.068	219

	Table 4.1:	Experimenta	1 Vs	FEA	Results
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The proposed bracket is feasible and carried forward for manufacturing to enhance the performance of material handling overhead crane.



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## 5. CONCLUSION

After simulation the results were evaluated. As shown in figures von mises stress and deformation

- LM 25 Alloy +Sic specimen is 230 MPa and 0.071 mm respectively. This value is within stress limits of respective materials. Therefore design is safe in tensile loading. In this project strengths can be verified by finite element analysis and experimental analysis. After successful measurements it was concluded that
- Stress values are within limit of design criteria for LM 25 Alloy +Sic specimen.
- > Deformation values are as per design criteria for LM 25 Alloy +Sic composite specimen.
- This LM 25 Alloy +Sic specimen will be corrosion free hence friction noise problem will be no more and no need of greasing or corrosion resistance coating.
- > Loading deflection ANSYS results of FEM and Experiment are similar.

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