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Structural Design and Optimization of an Industrial Lift Platform Using Composite Profiles

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Abstract*—The structural design and optimization of an industrial lift platform through the application of composite profiles, specifically sandwich structures, to enhance performance characteristics compared to conventional metallic (steel)designs. The primary goal is to significantly reduce the platform's overall weight without compromising essential safety factors and functional requirements, such as load-bearing capacity and stiffness. The methodology under development involves detailed 3D models of the lift platform using CAD software and performing extensive structural analyses, typically the Finite Element Method (FEM) in software like ANSYS Workbench. Various composite material properties and cross? sectional geometries (e.g., triangular, rectangular, circular cores) are explored and compared under simulated operational conditions, including static and dynamic loads. Optimization techniques, such as topology and size optimization, are applied to determine the most efficient design parameters for the composite structure. The results consistently demonstrate that platforms can achieve substantial weight savings, often in the range of 19% to 50% compared to steel structures, while meeting or exceeding strength and deflection limits. The findings confirm the technical feasibility and practical implications of using composite profiles for lightweight, high-performance industrial lift platforms, leading to potential benefits in cost savings, energy efficiency, and ease of transport. The study technically validates the feasibility of utilizing optimized composite sandwich profiles in the design of industrial lift platforms. Implementing these materials reduces weight, translating into practical benefits such as lower operational costs, improved energy efficiency, and longer service life. The outcomes of this research provide a robust design framework for future lightweight industrial-machinery components.

***Keywords*—Composite structures; industrial lift platform; structural optimization.**

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I. Introduction

Conventional steel industrial lift platforms are inefficient because of their heavy weight and increased interchangeability, which creates additional factors such as safety issues and higher functional requirements (e.g., load capacity and stiffness). To accomplish this task, detailed Building Information Modeling (BIM) of the lift platform using computer-aided design (CAD) software and extensive structural analysis, typically using the finite element method (FEM) in software packages such as ANSYS Workbench, are performed. Alternative composite material properties and cross-sectional geometry shapes (i.e., triangular/rectangular/circular cores) were investigated and tested under simulated operational conditions (e.g., static and dynamic load cases). In addition, optimization techniques, such as topology and size optimization, will be used to identify the most efficient design parameters for the composite lift support structure.

The repeated trial data show that composite platform constructions achieve 19%- 50% higher structural weight savings than steel platforms while meeting or exceeding deflection and strength guidelines. This technical analysis provides a history of the feasibility and benefits of using composite profiles for lightweight, high-performance Industrial lift platforms. Beyond potential cost savings and energy efficiency, these designs reduce a lift platform's total weight, lowering operational costs, increasing efficiency, and extending service life. This investigation provides a comprehensive design basis for all future lightweight Industrial Machinery Components. Core selection depends on the proposed usage; however, established core types such as tube- or hat-shaped cores are typically more readily available and meet the industrial marketplace's tolerances and requirements for laser welding. Non-standard cores, such as corrugated or I-shaped cores, require specific manufacturing equipment but produce the lightest panels.

A. *Literature review*

This section contains a detailed literature review of previous research studies on the structural design and optimization of an industrial lift platform using composite profiles. The preceding section outlines some selected research studies. In factories, warehouses, and maintenance areas, an industrial lift platform lifts individuals or objects vertically. Most lift platforms are made of steel, which makes them heavier and uses more energy. Hybrid composite materials, such as carbon–Glass Epoxy composites, are used to improve performance. Hybrid composites combine the high stiffness of carbon fiber with the toughness and lower cost of glass fiber to create a structure that is strong, lightweight, and corrosion-resistant.

Mane [1] designed and analyzed composite structures for industrial platforms, focusing on weight reduction without compromising strength and stiffness. They selected three core geometries (triangular, rectangular, and circular) for sandwich panels and conducted finite element analysis using ANSYS Workbench and experimental testing using a UTM machine. They initially created the models in CATIA.

Gopichand et [2] have carried out the structural analysis. In this research, they analyzed corrugated sandwich panels with stainless steel face sheets and a mild steel core using ANSYS Workbench. The study aimed to compare the structural analysis results with experimentally obtained compressive strength values. The investigation focused primarily on flat composite panels, evaluating how their unique construction influences their mechanical properties and overall performance under load.

Ambule and Kolhe [3]showed that composite materials and sandwich panels offer a higher strength-to-weight ratio and lower weight, enabling the development of efficient structures through new materials or innovative structural designs. Composite materials and sandwich panels are a proven solution, offering a high strength-to-weight ratio with minimal weight. This highlights the advantages of composite sandwich structures for lightweight applications.

Cote et al [10] studied the in-plane compressive response of pyramidal truss-core sandwich columns. The identified failure mechanisms include Euler buckling, shear buckling, and face wrinkling. In their study, *they* examined the in-plane compressive behavior of a pyramidal truss-core sandwich.

Tale et al [4] has focused on steel Sandwich Plate Systems (SPS), which have been used for commercial applications during the last 15 years. In recent years, they have been used in a wide variety of applications across sectors. They provide a high strength-to- weight ratio. Offer impact resistance and fatigue durability and are used in civil engineering (bridges, floors, walls, offshore platforms). Applied in marine and shipbuilding industries (hulls, decks). Increasingly applied in mechanical and industrial sectors due to versatility. Stainless steel. structures provide a combination of low weight, high stiffness, and improved load-bearing capacity, making them highly effective in advanced structural design. The visual appeal of stainless steel makes it suitable for visible ceilings. This allows designers to group cables and fluids in suspended trays, which creates more free headroom above the floor.

Pokharel and Mahendran [5] have conducted a comparative study of past research on the local buckling behavior of fully profiled sandwich panels, based on polyurethane foams and thicker lower-grade steels. A study by [6] has conducted a comparative study of the science and rapid growth of engineering needs for suitable structural analysis software, FEM analysis. A combination of hardware and software resources gives a complete geometric model of any assembly with an accurate Computer-Aided Three-Dimensional Interactive Application.

A study by [7] has shown that sandwich structures provide low weight, high stiffness, and improved load-bearing capacity, making them highly effective in advanced structural design. Gangurde et al. [8] have conducted a comparative study of composites and generally agree that future work needs to focus on hybrid validation (combining simulation with physical testing), developing better manufacturing processes.

Manoharrao and Jamgekar [9] focuses on analyzing and optimizing the weight of a hydraulic scissor lift used in industrial applications, addressing issues like deformation and stress under heavy loads. It uses the finite element method (FEM) to analyze stress, strain, displacement, and deformation, aiming to reduce weight and cost through design modifications.

In today's industrial landscape, demand for efficient, lightweight, high-performance lifting systems has intensified, particularly in manufacturing. However, achieving a 40% weight reduction while selecting materials for maximum strength-to-weight ratio presents a complex challenge. A fundamental engineering trade-off exists: reducing material to save weight inherently increases stress concentrations in the remaining structure, whereas mitigating this stress typically requires adding material, which increases weight.

Current approaches to resolving this dilemma are limited by an insufficient analysis of equivalent stress effects. Furthermore, comprehensive validation across numerical, experimental, and Finite Element Analysis (FEA) methods is lacking. Without this robust cross-validation, it is difficult to accurately assess the impact of significant weight variation on the overall structural behavior and reliability of the lifting systems.

II. Materials and Method

The industrial lift platform is an expertly engineered assembly composed of four key structural components that work in harmony to safely handle and distribute substantial loads. At the heart of this design is a hybrid composite laminate deck plate, the primary load-bearing surface. This innovative deck is lightweight yet robust, supporting a variety of materials without compromising strength. Composite frame members surround the deck, crafted from rectangular hollow hybrid profiles to provide added sturdiness and resilience. Specialized support brackets anchor these frame members to the active lifting system, ensuring a secure, stable connection that enhances overall functionality. At the base of the assembly is a foundational frame that acts as the grounding element, stabilizing and reinforcing the entire structure. Together, these components create a reliable and efficient lift platform capable of managing significant weight while prioritizing safety and durability.

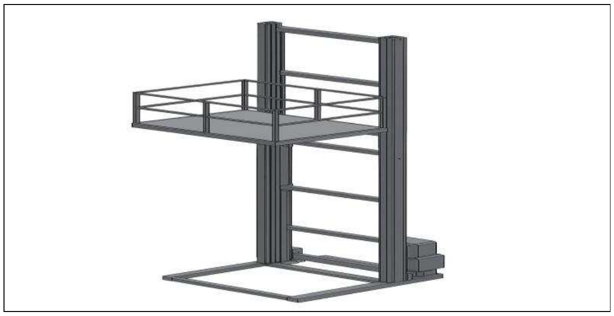

Fig. 1 Industrial lift platform

To create a hybrid composite material, combine carbon fiber and glass fiber with an epoxy resin matrix. This unique fusion harnesses the strengths of both carbon and glass fibers, resulting in a lightweight yet exceptionally durable material. Carbon fibers provide high tensile strength and stiffness, while glass fibers add impact resistance and flexibility. The epoxy matrix binds the fibers, ensuring a cohesive structure that enhances the composite's overall performance and longevity. This innovative material is ideal for applications requiring a combination of strength, durability, and lightweight properties.

Table 1 illustrates the advantages of hybrid composites by comparing the physical and mechanical properties of three distinct materials: Carbon Fiber, Glass Fiber, and a Hybrid Carbon-Glass Epoxy. It specifically compares the materials across the following properties:

- Density (g/cm³)
- Tensile Strength (MPa)
- Elastic Modulus (GPa)
- Corrosion Resistance

TABLE I
ADVANTAGES OF HYBRID COMPOSITE

Property	**Carbon Fiber**	**Glass Fiber**	**Hybrid Carbon-Glass Epoxy**
Density	1.6 g/cm³	2.5 g/cm³	1.8g/cm³
Tensile Strength	600 MPa	200 MPa	500 MPa
Elastic Modulus	200 GPa	50 GPa	120 GPa
Corrosion Resistance	Excellent	Excellent	Excellent

Table 1 outlines the material advantages of hybrid composites alongside the specific engineering design parameters for an industrial lift platform. It first highlights that hybrid composites offer greater strength than pure Carbon Fiber Reinforced Polymer (CFRP) at a lower cost, while also providing superior impact resistance, high fatigue strength, and excellent corrosion resistance. Building on these material benefits, the document then details the lift platform specifications, which are engineered with a safety factor of 2 and a load capacity of 400 kg. The platform measures 1200 mm long, 1000 mm wide, and 27 mm high, and its frame is constructed from hybrid composite rectangular profiles.

A. Load Calculation

To evaluate the load and bending stress for the platform frame, the initial static force is determined by multiplying the 400 kg maximum load by gravity (9.81 m/s²), resulting in a base force of 3924 N. Applying a safety factor of 2 yields a design load of 7848 N. Assuming the frame functions as a simply supported beam with a length of 1.2 m and a centrally applied point load, the maximum bending moment is found using the equation $M = (W \times L) / 4$, which evaluates to (7848 N × 1.2 m) / 4 to yield 2354.4 Nm. By applying a section modulus (Z) of 6×10^{-6} m³ for the hybrid composite profile, the maximum bending stress is calculated using the standard formula $\sigma = M / Z$. Dividing the 2354.4 Nm bending moment by the 6×10^{-6} m³ section modulus results in 392,400,000 Pa, or 392.4 MPa. Therefore, your calculations and final rounded result of 392 MPa are mathematically accurate, with only minor typographical errors in your original text regarding the bending moment unit (Nm instead of N) and the inverted notation of the stress formula. The strength of hybrid carbon-glass epoxy is about 500 MPa. So, the design is structurally safe.

TABLE II
COMPARATIVE ANALYSIS OF VARIOUS ENGINEERING MATERIALS

Material	**Category**	**Density (g/cm³)**	**Tensile Strength (MPa)**
Mild Steel (A36)	Conventional Metal	7.85	400
Aluminum Alloy (6061-T6)	Light Metal	2.70	310
GFRPE-glass/Epoxy)	Composite	1.90	900
CFRP (Carbon/Epoxy)	Composite	1.60	1500
Hybrid Composite (Carbon-Glass/Epoxy)	Composite Hybrid	1.75	1200

Table 2 provides an in-depth comparative analysis of a range of engineering materials, meticulously organized by material type, which includes conventional metals, lightweight metals, and advanced composite materials. This evaluation focuses on two fundamental properties: Density (measured in grams per cubic centimeter, g/cm³) and Tensile Strength (expressed in megapascals, MPa).

The table juxtaposes traditional structural materials such as Mild Steel and Aluminum Alloy with cutting-edge composites like Carbon Fiber Reinforced Polymer (CFRP) and a Hybrid Carbon-Glass/Epoxy composite. This comparison highlights the remarkable strength-to-weight ratios of the composite materials. Notably, these advanced materials achieve significantly higher tensile strengths while maintaining a much lower density than their conventional metal counterparts, showcasing their potential to revolutionize engineering applications where performance and weight efficiency are paramount.

Fig. 1 displays two side-by-side photographs of computer monitors showing different stages of the Computer-Aided Design (CAD) process for a structural component. The left panel shows a completed 3D solid model of a flat, rectangular plate rendered in a 3D modeling environment, while the right panel shows a 2D drafting interface with multiple geometric sketches and layout views used to define the part's profiles.

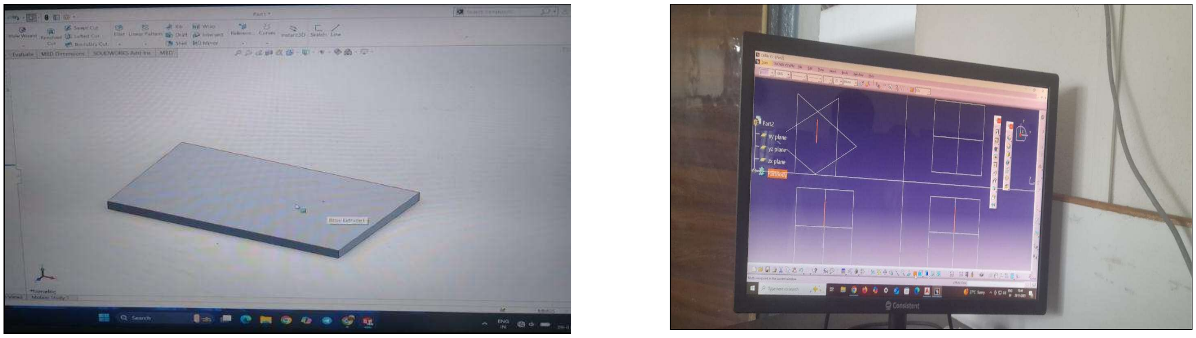

Fig. 2 2D and 3D model assembly figures. Length (1200mm). Width(1000mm). Height(27mm)

According to the accompanying caption, these digital models represent an assembly defined by specific physical dimensions: 1200 mm length, 1000 mm width, and 27 mm height. These measurements match the design specifications for the industrial lift platform deck, showing how the platform's spatial requirements were translated into digital geometric models for further engineering analysis and manufacturing preparation.

B. Numerical Analysis

1) Platform Geometry

The industrial lift platform was modeled in ANSYS Workbench for structural analysis. The platform geometry was assumed to be a rectangular plate supported by composite profiles. The table specifies the geometric dimensions—length, width, and thickness in millimeters—of an industrial lift platform. These parameters are being used to model the platform as a rectangular plate for structural analysis in ANSYS Workbench.

TABLE III
PLATFORM GEOMETRY PARAMETERS AND VALUE

Parameter	Value
Length	1200 (mm)
Width	1000 (mm)
Thickness	27 (mm)

The platform frame consists of hybrid composite profiles made of carbon fiber-reinforced polymer and glass fiber-reinforced polymer, combined with an epoxy matrix to achieve high stiffness, corrosion resistance, and reduced weight

TABLE IV
MATERIAL PROPERTIES (CARBON–GLASS REINFORCED EPOXY)

Property	Value
Density	1600 kg/m³
Young's Modulus (Ex)	85 GPa
Young's Modulus (Ey)	65 GPa
Young's Modulus (Ez)	10 GPa
Poisson's Ratio (vxy)	0.15
Poisson's Ratio (vyz)	0.40
Poisson's Ratio (vxz)	0.40
Shear Modulus (Gxy)	5 GPa

The material was defined in ANSYS as an orthotropic composite material because its mechanical properties vary by direction.

Fig. 3 Design of an industrial lift platform using composite profiles

2) Boundary Conditions

The following boundary conditions were applied in ANSYS:

- Fixed Support: Applied at the base frame connection points of the lift platform.
- Load Condition: Uniform load applied on the top surface of the platform representing industrial lifting load.
- Assumed Load Capacity: 400 kg

Load Calculation:

Load=400×9.81

Load=3924N

The load was distributed uniformly across the platform surface.

3) Meshing

A fine mesh of tetrahedral elements was generated to improve simulation accuracy.

- Typical mesh parameters:
- Element type: Solid186
- • Number of nodes: ~45,000
- • Number of elements: ~22,000

Mesh refinement ensured accurate stress and deformation predictions in composite regions.

III. RESULTS AND DISCUSSION

A. ANSYS Simulation Results

1) Total Deformation: Maximum deformation occurred at the center of the platform surface due to the applied load.

2) Maximum deformation: Total Deformation≈1.2 mm. This deformation value is within the acceptable range for industrial lifting platforms.

3) Equivalent (Von-Mises) Stress: The Von-Mises stress distribution shows maximum stress concentration near support regions and frame joints.

4) Maximum Equivalent Stress: σmax≈48 MPa. This value is significantly lower than the allowable stress of carbon-glass epoxy composites (≈ 300–500 MPa). Thus, the platform structure is structurally safe under the applied load.

5) Equivalent Elastic Strain: The maximum strain observed in the platform was: Equivalent Strain≈0.00065. This strain value confirms that the material operates well within the elastic region.

6) Safety Factor: The factor of safety was calculated using the relation:

FOS=35048
FOS=Maximum Stress Material Strength
Assuming composite tensile strength ≈ 350 MPa
FOS≈7.29

The high safety factor indicates excellent structural reliability and load-bearing capability. The ANSYS structural analysis of the industrial lift platform using carbon-glass-reinforced epoxy composite profiles shows that maximum deformation is very small (≈1.2 mm). Stress levels remain well below the material strength limit. The platform exhibits a high factor of safety (7). Composite materials significantly reduce structural weight while maintaining high stiffness and strength. Therefore, carbon–glass reinforced epoxy composite profiles are suitable for industrial lift platform applications**,** providing improved durability, corrosion resistance, and lightweight structural performance compared to conventional steel structures. Fig. 4 below shows the manufacturing of an industrial lift platform.

Height1000mm Thickness27mm C]Length 1200mm

Fig. 4 Manufacturing of an industrial lift platform

B. Meshing Method

For a 27 mm thick hybrid carbon/glass-reinforced epoxy base plate, a standard shell mesh can introduce errors. The following meshing strategy in ANSYS Workbench ensures structural accuracy for such a thick industrial component: Solid Model Extrusion (Recommended): For a 27mm plate, use ANSYS Composite PrepPost (ACP) to generate a "Layered Solid Model". This extrudes a 3D volume from a 2D shell mesh, representing each ply or group of plies with 3D solid elements.

Number of nodes in an industrial lift platform using composite material: ~45,000. Meanwhile, the number of elements: ~22,000. The mesh refinement ensured accurate stress and deformation prediction in composite regions

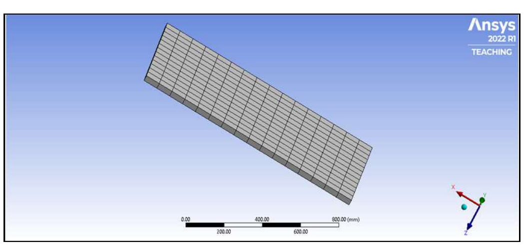

Fig. 5 Meshing method

C. Geometry Setup

Geometry Setup: To model the 1200mm x 1000mm x 27mm hybrid composite base plate in Ansys Workbench, follow this specific geometry and material setup for accurate FEA.

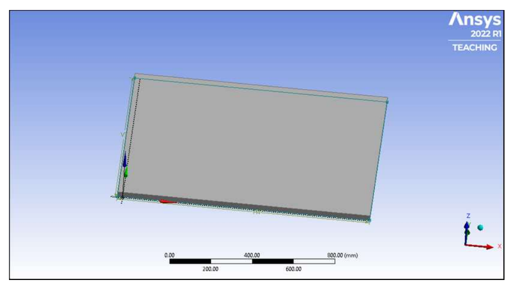

Fig. 6 Geometry setup

D. Fixed Support

To complete your analysis of the 1200mm x 1000mm x 27mm composite platform in Ansys Workbench (Static Structural), you must define how the platform is held (Supports) and how the industrial weight is distributed (Loads), Boundary Conditions (Supports). Since this is a lift platform, the supports are usually where the scissor arms or rollers meet the base plate. Fixed Support: Apply this to the two points (or small edges) where the scissor arms are pinned to the plate. This prevents all translation and rotation.

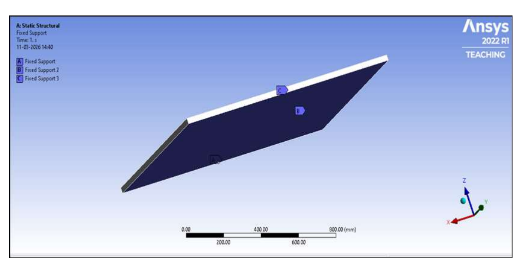

Fig. 7 Fixed support

E. Load Condition

Load Application (The "Lift" Force):

- Pressure Load (Recommended): If the load is a pallet or crate, apply a Pressure to the top face.
- Load Condition: Uniform load applied on the top surface of the platform, representing an industrial lifting load.
- Assumed Load Capacity: 400 kg
- Load Calculation: Load=400×9.81; Load=3924N.

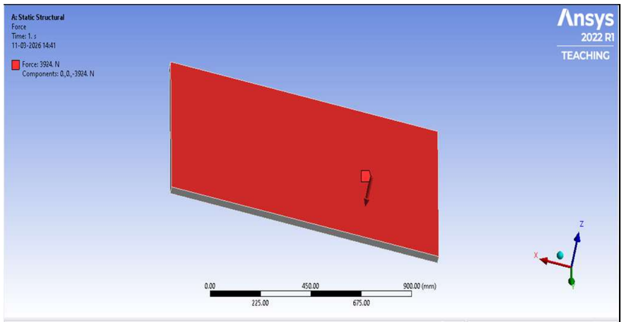

Fig. 8 Load condition

F. Stress Analysis

To analyze the stress in your 27mm thick Carbon-Glass/Epoxy platform using Ansys Workbench, you cannot rely on standard "Equivalent (Von Mises) Stress" alone. Because composites are isotropic (properties vary by direction), you must evaluate stress layer-by-layer.

- Normal Stress in Fiber Direction): Check this for the Carbon Fiber skins (top/bottom). This shows if the fibers are snapping under tension or buckling under compression.
- Maximum Equivalent Stress: σmax≈48 MPa

This value is significantly lower than the allowable stress of carbon-glass epoxy composites (≈ 348 MPa). Thus, the platform structure is structurally safe under the applied load.

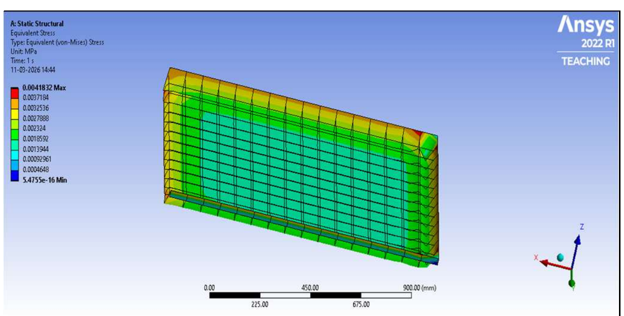

Fig. 9 Load condition

G. Deformation (Deflection)

Find the Deformation (deflection) on a 1200 mm x 1000mm x 27mm composite platform in Ansys Workbench. Follow these specific steps in the Static Structural and ACP (Post) modules.

Total Deformation≈1.2 mm. This deformation value is within the acceptable range for industrial lifting platforms.

H. Summary of the Results

To compare the performance and cost-effectiveness of the composite design with a conventional steel- based platform.

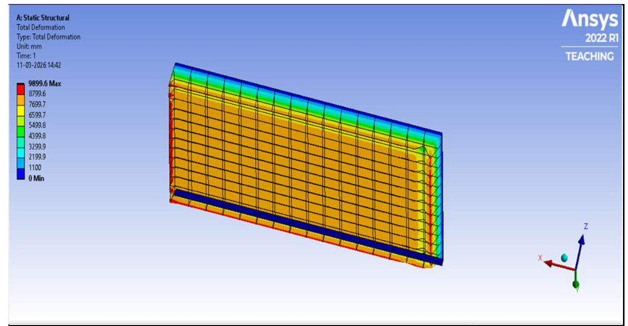

Fig. 10 Deformation (deflection)

TABLE V

THE COMPARISON BETWEEN THE PERFORMANCE AND COST-EFFECTIVENESS OF THE COMPOSITE DESIGN WITH A CONVENTIONAL STEEL-BASED PLATFORM

Feature	Carbon/Glass Reinforced Epoxy	Conventional Steel
Weight	Very Low (75-80% reduction)	High
Corrosion Resistance	Excellent (Immune to rust)	Poor (Requires coatings)
Tensile Strength	High (Fiber-directional)	Moderate to High
Ductility	Low (Brittle failure)	High (Predictable failure)
Initial Cost	High	Low

Table 5 compares the performance and cost-effectiveness of a carbon/glass-reinforced epoxy composite design against a conventional steel-based platform across five key features. The composite material offers significant physical advantages, including a 75-80% reduction in weight, excellent rust immunity, and high fiber-directional tensile strength, though it suffers from low ductility (leading to brittle failure) and high initial costs. Conversely, conventional steel provides better ductility for predictable failure and a lower initial cost, but it is heavy and has poor corrosion resistance that requires protective coatings.

I. Discussion

The structural design and optimization of industrial lift platforms using composite profiles mark a shift from traditional heavy steel frameworks to lightweight, high-strength composite materials. This innovation aims to improve operational efficiency while significantly reducing overall energy consumption.

1) Weight Reduction: Composite platforms typically achieve an impressive weight reduction of around 40% when compared to their conventional steel counterparts [10]. This weight reduction not only makes handling and installation easier but also lowers operating energy requirements.

2) Strength Improvement: Interestingly, despite the lower weight, composite structures frequently demonstrate greater equivalent stress strength [11]. This means they can withstand the same or greater loads than steel while being lighter, making them an appealing choice for industrial applications.

3) High Strength-to-Weight Ratio: The superior strength-to-weight ratio of composite materials allows for substantial weight savings of up to 45% [12], [13], [14]. All while maintaining the necessary structural integrity and safety. This characteristic is essential for lift platforms, where both strength and lightness are pivotal to optimal performance.

4) Corrosion Resistance: One of the significant advantages of using composites is their inherent resistance to corrosion [15]. Unlike steel, many composite materials do not rust or corrode, which greatly reduces inspection frequency and the need for costly structural repairs over time [16], [17], [18], [19].

5) Load-Bearing Efficiency: Moreover, the directional fiber patterns of composite materials can be meticulously arranged to effectively sustain applied loads in accordance with specific design requirements [20], [21], [22], [23], [24]. This customization improves performance in various industrial settings, ensuring lift platforms can meet diverse operational demands efficiently.

IV. Conclusion

Implementing carbon-glass reinforced epoxy composite profiles for industrial lift platforms provides a highly effective, lightweight alternative to conventional steel structures. Finite element analysis validates that these optimized composite structures can achieve substantial weight savings—typically between 19% and 50%—without compromising structural integrity or load-bearing capacity. Under simulated operational conditions, the composite platform showed a minimal maximum deformation of about 1.2 mm and a maximum equivalent stress of 48 MPa, well below the material's strength limit and yielding a safety factor of roughly 7.29. In addition to a superior strength-to-weight ratio, the composite design enables customized load-bearing efficiency through directional fiber patterns and offers inherent corrosion resistance that reduces the need for ongoing maintenance. Ultimately, replacing heavy steel frameworks with optimized composite sandwich profiles lowers operational costs, improves energy efficiency, and extends the platform's service life, establishing a robust design framework for future industrial machinery.

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