Comprehensive Investigations on CF-GY-70 Reinforced Single and Multi-Walled Nanocomposites for UAV Landing Components Using Validated Engineering Techniques

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**Abstract.** Durability is vital in demanding real-time applications such as Aerospace, Automotive, and Marine. Drone components are particularly susceptible to fractures due to their intricate design and aerodynamic challenges. Thorough research into the failure factors of these components is crucial to enhance their deployment in targeted activities. The study rigorously investigates the structural performance of an epoxy resin matrix incorporating carbon fibers and carbon nanotubes, employing a combination of experimental testing and numerical simulations to validate the findings. In this study, the conventional GY 70 epoxy is paired with the Single-walled carbon nanotubes (SWCNTs) and multi-walled carbon nanotubes (MWCNTs), and their strength, deformation, and strain are all studied. It is found that under compression test, CF-GY-70 epoxy with SWCNTs work the best, giving the lowest deformation while the MWCNTs perform well than the conventional ones.

# INTRODUCTION

Carbon nanotubes (CNTs) are carbon tubes with sizes on the order of nanometers. The structural performance of engineering components are propellers, bumpers, fuselages, and wings are crucial. Lightweight, high-strength, and low-cost materials are essential for selecting components. However, lightweight materials may be less durable due to the difficulty in preserving their structure. Structural problems can arise from factors such as the complexity and positioning of coaxial rotors, sudden loads causing bumper failure, and the strong impact of hydrodynamic mediums on aquatic vehicles and parts. To address these issues, materials like Single-walled carbon nanotubes (SWCNTs) and multi-walled carbon nanotubes (MWCNTs)-based polymer matrix composites, metal matrix composites, sandwich composites, and hybrid composites are being considered for their ability to improve structural integrity while remaining lightweight and strong.

## Literature Survey – Principal and Secondary Components

Component In composite materials, fibers play an essential role in load resistance. Because the fibers themselves are responsible for the rigidity of the laminate, composites have a very high stiffness-to-weight ratio. The distribution of loads among fibers influences load bearing [1]. Because of this, an effective assessment of fiber orientation is required [3]. There are three different types of fiber that can be used to make composites: uni-, bi-, and multi-directional. Fibers can be made from a variety of materials including carbon, glass, boron, and so on [2]. The effectiveness and durability of composite laminates are directly proportional to the fiber foundation of the material [4]. The positive chemical reaction that occurs between composite fibers and other materials can result in an improvement in the material's thermal, electrical, and mechanical properties [5]. A high composite laminate efficiency is achieved by having a secondary component that supports both direct and indirect reinforcing [6]. The basic function of the matrix is to withstand delamination. The formation of composite laminates is dependent on the internal chemical reaction of the matrix and the fibers; hence, the selection of the matrix in relation to the base fibers is essential for ensuring a long life [7]. Epoxy resin, polyester, and other materials are all capable of performing the function of a composite matrix; however, epoxy resin is superior in terms of suitability and dependability for all fibers; hence, it can be utilized as the top matrix [8].

# IMPOSED METHODOLOGY – INTEGRATED COMPUTATIONAL APPROACH

A clear understanding of the formulations involved in flexural analysis is fundamental to achieving accurate and reliable simulation outcomes. This process begins with the development of a finite element model, followed by the construction of a computational framework, application of suitable boundary conditions, and validation of the analytical approach. Each step plays a pivotal role in ensuring the fidelity of the simulation to real-world behavior.

To replicate real-life structural responses, the geometry must be subdivided into finite elements. Fine discretization is particularly important for capturing intricate geometries and stress distributions under various loading scenarios [9–12]. Mesh generation incorporates both two-dimensional and three-dimensional features across structural and non-structural elements, and the mesh quality significantly influences the accuracy and convergence of simulation results [13–15].

Boundary conditions are equally critical, as they define the constraints imposed on the model such as fixed supports, applied forces, or symmetry planes which are essential for replicating actual operating environments [16–18]. In flexural analysis, these boundary definitions help initialize the simulation and govern the behavior of the system under load [32-48].

The effectiveness of mesh and boundary setups is typically evaluated using numerical simulations in computer-aided engineering environments [19-22]. A well-constructed model with appropriate meshing and clearly defined boundary conditions can closely mirror physical experiments, enabling precise detection of stress concentrations and minimal deformations [23–26]. This methodological approach helps engineers identify potential failure zones, optimize material usage, and refine structural designs, ultimately leading to more efficient, resilient, and safer engineering solutions [27-31].

# Results And Discussions

To understand the behavior of composite materials containing SWCNTs and MWCNTs, the conventional GY 70 epoxy is first tested under compression, followed by tests involving the CNTs.

## Computational analysis of CF-GY-70 epoxy Carbon fiber material under compression test

The GY70 epoxy material reveals its fundamental mechanical characteristics when it is employed in landing gear applications and tested for compression without incorporating CNT reinforcement. Studies show that CF-GY-70 epoxy carbon fiber composites are engineered to satisfy strict demands for strength and rigidity under axial compression and bending forces, especially when paired with ultra-high modulus graphite fibers. These materials display an impressive capacity to endure substantial compressive forces, which is vital for structural applications like landing gear, as demonstrated through static testing. Even though carbon nanotubes are not included in this case, the epoxy's ability to resist deformation under axial loads mainly relies on its compressive strength. The improvements in toughness and crack resistance that CNTs typically offer may be restricted in their absence [49-55]. Figures 1 to 4 presents the comprehensive structural analysis of CF-GY-70 epoxy carbon fiber for a compression load.

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| --- | --- |
|  |  |
| 1. Total deformation of base material | 1. Equivalent stress of the base material |
|  |  |
| 1. Equivalent elastic strain of the base material | 1. Strain energy of the base material |

## Computational analysis of CF-GY-70 epoxy composite associated with SWCNTs under compression test

In landing gear applications, the CF-GY-70 epoxy composite shows improved mechanical properties that are essential for aerospace construction, especially when reinforced with SWCNTs. These SWCNTs help reduce the natural brittleness of untreated CF-GY-70 by acting as nano-reinforcements, enhancing the composite's fracture toughness, crack resistance, and load transfer efficiency due to their exceptional strength-to-weight ratio and high aspect ratio [56-66]. As demonstrated in advanced aerospace composites, incorporating SWCNTs can decrease the risk of delamination and improve energy absorption during impacts or cyclic loading, which landing gear experiences from compression and bending forces. Figures 5 to 8 present the comprehensive structural analysis of GY 70 Epoxy associated with MWCNTs for compression load [67-71].

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| --- | --- |
|  |  |
| 1. Total Deformation of SWCNT material | 1. Equivalent stress of SWCNT material |
|  |  |
| 1. Equivalent elastic strain of SWCNT material | 1. Strain energy of SWCNT material |

## Computational analysis of CF-GY-70 epoxy associated with MWCNTs under compression test

The mechanical properties of CF-GY-70 composite materials for landing gear applications can be significantly improved by incorporating MWCNTs. Due to their exceptional strength, stiffness, and toughness, MWCNTs enhance the overall durability of the composite, increasing its resistance to impact and fatigue. By integrating MWCNTs, the CF-GY-70 composite exhibits greater load-bearing capacity, reduced weight, and improved thermal stability, making it more suitable for demanding aerospace applications. Furthermore, this incorporation can decrease the risk of structural failure under high-stress conditions, such as those encountered during landing operations. Therefore, including MWCNTs is essential for optimizing the performance of CF-GY-70 composite components in landing gear. Figures 9 to 12 present the comprehensive structural analysis of CF-GY-70 epoxy associated with MWCNTs for compression load.

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| --- | --- |
|  |  |
| 1. Total deformation of MWCNT material | 1. Equivalent stress of MWCNT material |
| A blue and green striped object  Description automatically generated | A green and blue column  Description automatically generated |
| 1. Equivalent elastic strain of MWCNT material | 1. Strain energy of MWCNT material |

## Comprehensive Study

Figures 13 to 16 present graphical representations of key structural parameters—namely, equivalent stress, total deformation, equivalent elastic strain, normal stress, and strain energy for CF-GY 70 epoxy composites, both with and without the inclusion of SWCNTs and MWCNTs.

1. Total deformation of GY 70 Epoxy with and without CNTs
2. Equivalent stress of GY 70 Epoxy with and without CNTs
3. Equivalent elastic strain of GY 70 Epoxy with and without CNTs
4. Strain energy of GY 70 Epoxy with and without CNTs

# Conclusion

All fundamental data, encompassing three-dimensional information, mechanical properties of the materials utilized, boundary conditions, and the careful selection of both main and sub-elements of the nanocomposite involved in this study, have been meticulously gathered through a comprehensive literature survey. The pre-processing phase of this simulation methodology is executed using ANSYS software, which is recognized for its robust capabilities in finite element analysis. Throughout the investigation into the diverse characteristics of advanced nanocomposites, it became evident during compressive testing conducted with an applied load of 12749 N that the combination of GY 70 epoxy with SWCNTs demonstrated superior performance. In the comparative analysis between SWCNTs and MWCNTs, a significant observation is that MWCNTs, when combined with GY 70 epoxy, resulted in a higher total deformation under similar loading conditions. This leads to the conclusion that, for this composite material configuration, the incorporation of SWCNTs enhances structural performance and integrity. With a deeper understanding of the infusion of carbon nanotubes in traditional composites, there lies great potential for the development of an array of new materials tailored for diverse applications across various industries. The insights gained from this study could pave the way for innovations that leverage the unique properties of these nanocomposites, ultimately contributing to advancements in technology and material science.

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