ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 3, 2019

THE INVESTIGATION AND ANALYTICAL APPROACHES TO UNDERSTAND THE BEHAVIOR OF THIN CYLINDRICAL PANELS SUBJECTED TO MECHANICAL LOADS.

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Abstract

Applications for shell structures are numerous and include cooling towers, pipelines, aircraft, marine construction, big dams, shell roofing, and liquid-retaining structures. Weight reduction is a key design goal for these structures since it improves system performance. Composite materials can be used to achieve this, which provide more specific stiffness and strength than conventional metallic structures. This research aims to determine the deformation and stress characteristics of a thin cylindrical panel with and without a hole by performing static, linear buckling, and linear layer studies. Panels made of CFRP (Carbon Fiber Reinforced Plastic), glass fiber reinforced plastic, and aluminum alloy 8011are included in the analysis. Panels of three, six, and nine layers are examined using the layer stacking technique. Software analysis is done with ANSYS, while CATIA, a parametric program, is used to model the panels in three dimensions. This paper mainly focuses on the determination of the stress in thin cylindrical panels made of conventional and composite materials. This paper also attempts to examine how layer geometry affects the panels' performance. The research findings provide significant understanding of how these structures behave under different loading scenarios, which helps optimize their design for improved performance.

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Key words: Carbon Fiber Reinforced Plastic, geometry, cylindrical panel, ANSYS

1. Introduction

Thin-walled cylindrical shells serve as essential structural components in mechanical, civil, aerospace, and nuclear engineering. These shells, composed of metallic and laminated composite materials, find applications in underwater, air, surface, and space vehicles, as well as in the construction of pressure vessels, liquid storage tanks, and storage bins [1]. However, manufacturing processes may introduce geometric irregularities, significantly reducing the buckling load of these shells [2]. Given the relatively small thickness of these structural elements, buckling is often identified as the primary failure mode. As a result, understanding the buckling strength and behavior of thin shells has been the focus of numerous analytical and experimental investigations [3]. Moreover, composite structures play a pivotal role in diverse industries such as aerospace, marine, aircraft, ships, and automotive. Many of these structures face the risk of blast loading during war, accidental explosions, or terrorist attacks. Consequently, analyzing the response of composite structures to explosions has become a crucial area of research in recent decades. Composite plates and shells constitute fundamental elements of these structures, and studying their blast response contributes to enhancing their blast resistance [4].

Cylindrical shells are widely used in numerous engineering applications, such as underwater vehicles, military, aerospace and pressure vessels [5]. The buckling of cylindrical shells is a crucial parameter in mechanics and is frequently encountered in various applications. Cylindrical shells serve as closed containers for storing fuel or gas under pressure higher than atmospheric pressure. Different shapes and sizes of cylindrical shells are utilized in offshore industries. Among these various different types of shells, cylindrical shells holds the particular importance. Researchers have been experimenting with changes in the sidewall design and materials used to increase the shells' load resistance and decrease their weight. Due to the variety of shells used in different industries, the design and installation of these reservoirs are

of paramount importance. These are subjected to different types of mechanical loads including internal and external pressure, axial and radial loads, and thermal loads [6]. Analyzing the

ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 3, 2019

stresses and deformations induced by these loads is crucial for ensuring the structural integrity of the panels.

Analytical investigations play important role in determining the behavior of thin cylindrical panels under mechanical loads [7]. The classical theory of elasticity is often used to analyze these panels, which provides analytical solutions for different boundary and loading conditions. Furthermore, the Donnell-Mushtari-Vlasov theory considers the effects of rotating inertia and shear deformation, which are frequently overlooked in the classical theory. [8]. Another numerical method used for analyzing thin cylindrical panels is the finite element method (FEM). FEM discretizes the panel into small elements and solves the equations governing the behaviour of each element. FEM is advantageous in analyzing complex geometries and loading conditions [9]. Experimental testing is also an important aspect of investigating the behavior of thin cylindrical panels under mechanical loads. It provides valuable data for validating analytical models and developing design guidelines and standards. By combining analytical investigations and experimental testing, engineers can ensure the safe and efficient use of thin cylindrical panels in various applications [10].

2. METHODOLOGY

In structural integrity analysis, composites constitute a key consideration. Concrete, a commonly used artificial composite material, is formed by bonding stones using cement. It is an economical material that can sustain considerable compressive forces but lacks tensile loading resistance. To enhance concrete's tensile strength, reinforced concrete, consisting of steel bars, is frequently employed.

Fiber-reinforced polymers-FRPs are composed of materials such as glass-reinforced plastic (GRP) & carbon-fiber-reinforced polymer-CFRP. These composites can be classified based on matrix type, such as short and long fiber thermoplastics, thermoplastic composites, and long fiber-reinforced thermoplastics. Advanced thermoset polymer matrix systems, such as those containing aramid and carbon fibers in an epoxy resin matrix, are also available.

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Figure 1: Concrete

Concrete, a ubiquitous composite material, consists of cement, water, and aggregates, such as crushed stones, gravel, or sand. It is highly versatile and extensively utilized in construction due to its low cost, durability, and strength. The cement component acts as the binding agent, while the water and aggregates confer workability and strength to the mixture. The moldable nature of concrete enables it to be cast into diverse shapes and sizes, rendering it suitable for varied applications, ranging from building walls and foundations to bridges and roadways. Concrete strength and durability can be augmented by using different cement types, aggregates, additives, and appropriate curing and maintenance methods.

Organic matrix and ceramic aggregate composites are another category of composite materials. Asphalt concrete, polymer concrete, and dental composites are among the examples of these materials. Due to their unique characteristics, these materials are frequently used in construction and other industrial applications

3. Materials and methods

The mechanical properties of Aluminum alloy 8011, CFRP, E-glass fiber is presented in table-1.

Table 1: Mechanical Properties

Materials	Young's modulus (Mpa)	Tensile strength (Mpa)	Poisson's ratio	Density(kg/mm3)
Aluminum alloy 8011	69000	490	0.31	0.00000271
CFRP	228000	3900	0.30	0.00000020
E-glass fiber	72000	3441	0.21	0.0000024

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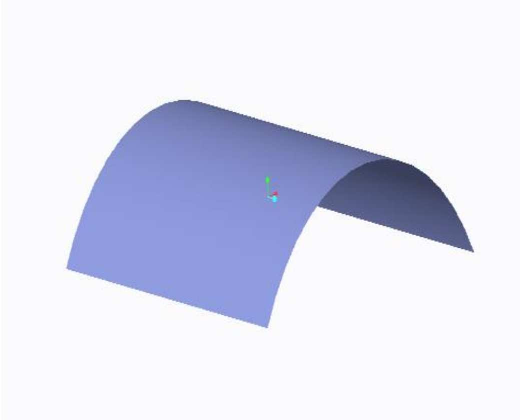
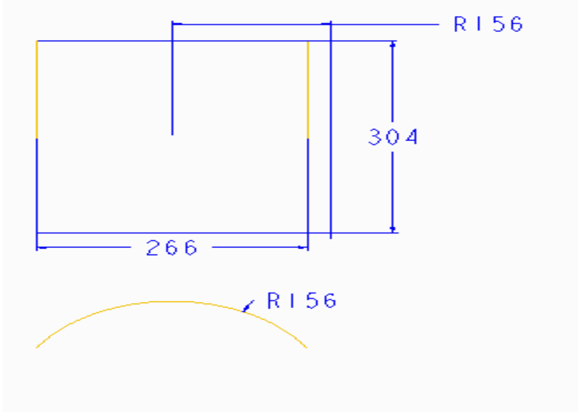
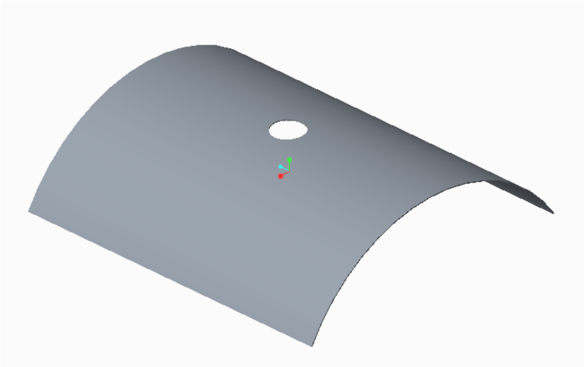


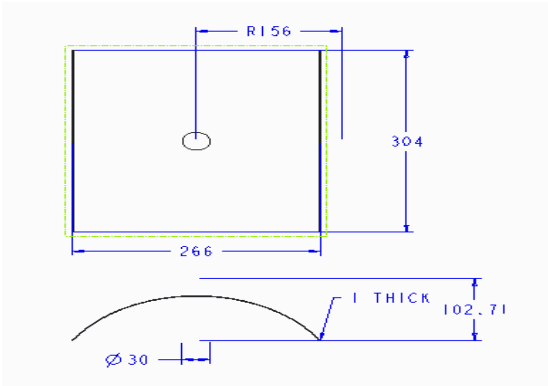
3D model



2D model



3D model



2D model

4. Introduction to ANSYS

ANSYS is a formidable and versatile software package that is utilized for finite element analysis (FEA), a numerical method used to scrutinize the conduct of complex systems by dissecting them into diminutive elements and unravelling equations governing the behaviour of each element. This methodology furnishes a profound perception of how a system performs and enables the design and optimization of systems that are too convoluted to scrutinize by hand. ANSYS is extensively employed in mechanical, civil, and electrical engineering, in addition to physics and chemistry departments.

4.1 Generic Steps to Solving any Problem in ANSYS

The process of solving a problem in ANSYS involves several steps that must be followed carefully to obtain accurate results. The first step is to clearly define the problem that needs to be solved, which includes identifying the type of analysis, material properties, & geometry.

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Next, a model of the geometry must be created using ANSYS geometry tools, either by importing an external CAD file or creating it within ANSYS. The geometry must then be divided into smaller elements using ANSYS meshing tools to ensure accurate results.

After meshing, boundary conditions such as loads, supports, and constraints must be applied, and the material properties must be defined. The appropriate analysis type must then be chosen based on the problem definition, and solver settings such as convergence criteria and element types must be defined.

Once the analysis is set up, it can be submitted to the solver to obtain results. These results must then be analyzed to ensure that they are accurate and meet the required criteria. If necessary, changes can be made to the model based on the results, and the analysis can be re-run iteratively until the desired outcome is achieved.

By following these steps, ANSYS users can solve a wide range of problems in various disciplines.

4.2 Carbon Fiber Reinforced Plastic

Fiber reinforced composites have gained traction in various industries because of their highest strength to weight ratio, non-conductive attributes, & cost-effectiveness. Of these, fiberglass is widely acknowledged as the "workhorse" owing to its adaptability and diverse range of applications. It competes admirably with conventional materials such as wood, metal, and concrete, and is extensively employed in manufacturing boats, airplanes, and wind turbine blades.

Fiberglass products offer multiple advantages over conventional materials. They are sturdier yet lighter, making them an ideal choice for applications where reducing weight is of paramount importance. Additionally, they are non-conductive, which renders them ideal for electrical and electronic applications. Fiberglass is also resistant to corrosion and chemicals, making it an appropriate material for deployment in challenging environments.

In conclusion, while fiberglass is a dependable and widely used material in the composites industry, various other reinforcing fibers exist that provide upgraded features for specific

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applications. By comprehending the distinctive qualities of these materials, engineers can select the most appropriate composite materials for their specific design requirements.

4.3 E- Glass fiber

Glass fiber is a widely utilized material in the composites industry due to its mechanical properties that are comparable to other fibers like carbon fiber and polymers.

4.4 Functionally Graded Materials (FGMs)

Functionally Graded Materials (FGMs) belong to the class of advanced materials that are deliberately engineered to possess continuously varying material properties along specific directions. These materials are constructed of two or more distinct substances that are specifically chosen to fulfill particular objectives, and their properties are gradually and accurately modified.

5. Conclusion

This project involves conducting static, linear layer and buckling analysis to decide the deformation, stress, strain of a cylindrical shell made from different materials, including aluminum alloy 8011, carbon fiber, glass fiber reinforced plastic, and FGM. The analysis was conducted on models created using CATIA parametric software and ANSYS software was used to perform the analysis. Both with and without holes were considered for each material. The static analysis revealed that increasing the loads led to increased deformation, stress, and strain values. Among the materials tested, the E-glass fiber material exhibited the lowest stress values compared to aluminum alloy 8011 and carbon fiber reinforced plastic. In the buckling analysis, the carbon fiber material had the highest buckling factor when compared to aluminum alloy 8011 and glass fiber reinforced plastic. The linear layer static analysis showed that the stress values were lower in the panel without holes than in the one with holes. Similarly, the linear layer buckling analysis showed that the buckling factor was higher in the panel without holes than in the one with holes. The study found that a functionally graded material (FGM) without holes is the best material and design for a thin cylindrical panel. This is because FGMs have varying properties throughout their thickness, which allows them to better withstand different types of loading conditions. The study also highlights the importance of performing a thorough analysis to determine the optimal materials and design for cylindrical shells.

ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 3, 2019

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