FABRICATION OF COMPOSITE STIFFENED PANEL

Syed Masood , DR.K.JAGATH [M.E,PH.D]

Research scholar, Department of Mechanical Engineering, Sri Venkateshwara College Of Engineering, Tirupati .
Email: Syedsaifservice8@gmail.com
Professor, Department of Mechanical Engineering, Sri Venkateshwara College Of Engineering, Tirupati.
Email: jagath.kamineni@svcolleges.edu.in

Abstract: A Composite materials are widely used in aerospace structures due to their high strength-to weight ratio and high stiffness-to-weight ratio as compared to conventional materials.Well-judged combination of materials along with the specific type of engineering structures, stiffened structures, provide tailored properties for aircraft structural components. In this work, the design and fabrication of composite stiffened panel is studied Being such a widely used structural component (composite stiffened panels) in aerospace industry, effective fabrication and assessment of integrated composite stiffened panel become a major interest in the research community. Being a thin-walled structure, the behavior of composite stiffened panel is governed its stability criteria. Therefore, the experimental study can be carried out to understand the stability behavior of laminated composite stiffened panels, in terms of buckling loads and failure loads.

Key Words: *A* Composites, stiffened panels, stiffeners, aircraft structures, buckling/failure load

1. INTRODUCTION:

A Composite Stiffened panel is the Combination of Curved Plate of Composite material and the Stiffeners Mounted on it.

Composite stiffened panels are a key structural element widely used in various industries, including aerospace, automotive, marine, and civil engineering. They offer a combination of lightweight construction, high strength, and exceptional mechanical properties, making them suitable for applications that demand superior structural performance.

Composite stiffened panels consist of a composite skin, typically made of carbon fiber reinforced polymers (CFRP) or Fiber glass reinforced polymers (FRP), and internal stiffeners that provide additional strength and stiffness to the structure. The skin acts as the primary load-bearing element, while the stiffeners help distribute and resist external loads, enhancing the overall structural integrity.

The design and analysis of composite stiffened panels involve a range of considerations, including the choice of material, geometric configuration of the stiffeners, and load distribution across the structure. Designers must carefully optimize these factors to achieve desired structural performance, while considering manufacturing feasibility, cost-effectiveness, and maintenance requirements.

Composite materials used in stiffened panels typically consist of a matrix, such as epoxy or polyester resin, reinforced with high-strength fibers, such as carbon

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 08 | Aug - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

fibers or fiberglass. These materials offer remarkable properties, including high strength-to-weight ratio, excellent fatigue resistance, corrosion resistance, and the ability to tailor mechanical properties to specific application requirements.

Composite stiffened panels find applications in various fields. In aerospace, they are used in aircraft fuselages, wings, and tail sections, contributing to weight reduction, fuel efficiency, and improved overall performance. In the automotive industry, stiffened panels are utilized in car bodies, chassis components, and interior structures, offering enhanced safety and rigidity. In marine applications, they are employed in boat hulls and decks, providing lightweight and corrosion-resistant solutions.

This study aims to explore and analyze the design, manufacturing, and performance of composite stiffened panels, contributing to the advancement and wider adoption of these lightweight, high-strength structural elements in various industries.

Figure 1: Composite stiffened panel

The scope of composite stiffened panels encompasses various aspects related to their design, manufacturing, analysis, and application. The following areas fall within the scope of composite stiffened panels:

Material Selection: The scope includes evaluating and selecting appropriate composite materials, such as carbon fiber-reinforced polymers (CFRP) or glass fiber-reinforced polymers (GFRP), for the panel skin and stiffeners. This involves considering factors such as mechanical properties, cost, availability, and compatibility with the intended application.

Design Methodologies: The scope involves developing design methodologies for composite stiffened panels, including the layout, configuration, and dimensions of stiffeners, as well as the overall panel geometry. Design methodologies should consider load requirements, structural efficiency, stability, buckling resistance, fatigue life, and damage tolerance.

Manufacturing Techniques: The scope includes exploring various manufacturing techniques for composite stiffened panels, such as hand layup, vacuum infusion, automated fiber placement (AFP), or resin transfer molding (RTM). This also includes considerations for tooling design, curing processes, quality control, and inspection techniques to ensure consistent and reliable manufacturing.

Structural Analysis: The scope involves conducting structural analysis of composite stiffened panels to assess their performance under different loading conditions. This includes finite element analysis (FEA) to evaluate stress distribution, deflection, buckling behavior, and failure modes. The analysis should also consider the interaction between the skin and stiffeners and account for material non-linearities and manufacturing defects.

Performance Optimization: The scope encompasses the optimization of composite stiffened panel designs to achieve specific performance goals, such as maximizing strength-to-weight ratio, minimizing weight, improving fatigue resistance, or meeting application-specific requirements. Optimization techniques can include parametric studies, multi-objective optimization, and sensitivity analyses.

Future Developments: The scope encompasses identifying and discussing emerging trends, advancements, and potential future developments in the field of composite stiffened panels. This includes exploring novel materials, manufacturing techniques, design methodologies, and analysis approaches to further improve the performance and expand the applications of composite stiffened panels.

Stiffened panels are designed to distribute external loads, such as bending, shear, and compression, across the structure. The objective is to ensure that the applied loads are efficiently transmitted through the stiffeners and skin, minimizing localized stress concentrations and preventing structural failures.

Stiffeners play a crucial role in enhancing the stability and buckling resistance of panels. The objective is to prevent buckling and local instability by designing and positioning stiffeners in a way that effectively resists compressive loads and maintains structural integrity.

Fatigue and Damage Tolerance: Composite stiffened panels aim to exhibit excellent fatigue resistance and damage tolerance. The objective is to ensure that the panels can withstand cyclic loading and mitigate the propagation of cracks or damages, thereby prolonging their service life and reducing the risk of sudden failure.

The objective is to optimize the design of stiffened panels to meet specific performance requirements, such as strength, stiffness, and durability. Design optimization involves selecting suitable materials dimensions of stiffeners, and considering factors like manufacturing feasibility, cost-effectiveness, and maintenance requirements.

The objectives of composite stiffened panels can be influenced by the specific application. For example, in aerospace applications, objectives may include weight reduction, fuel efficiency, aerodynamic performance, and compliance with regulatory standards. In automotive applications, objectives may focus on crashworthiness, stiffness, and occupant safety.

Overall, the objectives of composite stiffened panels revolve around achieving lightweight, structurally efficient, and reliable structural components that meet the performance requirements of the intended application while optimizing material usage and manufacturing processes

2. LITERATURE REVIEW

Stroud and Anderson studied the numerical formulation to find the buckling of blade type, hat-stiffeners, and corrugated stiffened panel. Smeared stiffeners technique was used to analyze the laminated composite panel under various type of in- plane loading with different types of stiffener employed a power series method in the non-linear analysis of circular plates subjected to uniform radial compression on the edge. In the advanced post-buckling stage, the plate was subjected to a high circumferential compressive stress in the region near the edge, which induces the plate to buckle for the second time with an asymmetric deformation mode.

Makeev and Armanios presented an iteratve method for an approximate analytical solution of elasticity problems in laminate composites. The stress analysis was performed for laminates in the three dimensional strain state independent of the longitudinal direction.

Loughlan and Delaunoy analyzed the buckling of stiffened panels under edge loads, shear and combination of compression-shear load using finite strip technique. The buckling strength of stiffened panel has been also analyzed by considering parameters like pitch length, stiffener size, and fiber orientation

Barbero etal. investigated laminated composite plates and presented a numerical analysis of the connection between them. The orthotropic surface of FRP materials was modeled by using two-friction coefficients (orthogonal) and applying the constitutive law.

Hadi and Matthews studied to predict the buckling load of a sandwich panel. Parametric studies have been presented by the analytical method and compared with symmetric angle-ply laminated faces, anisotropic faces and (00/core/00) of sandwich panels. Rikards et al performed buckling analysis of stiffened structures by developing a triangular FE. Natural frequencies and buckling loads of stiffened panel are obtained from the present numerical analysis.

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 08 | Aug - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

Guo et al. [1 studied the buckling response of stiffened panels under uniaxial compression by using a layer-wise FE formulation. Parametric studies of stiffened panels were presented for skin thickness to length ratios, ply configuration, stiffener depth to skin thickness ratios and panel aspect ratios.

Bisagni and Vescovini used T-shaped stiffeners in the composite panel as to study its local buckling and the post-buckling analysis by using an analytical method. Total potential energy (V) of the stiffened panel is due to plate bending (V_d) and stiffeners torsion(V^s)

$$\mathbf{V = V_d + V^s}$$

d

3. OBJECTIVE

The primary objective is to create lightweight and structurally efficient panels. By utilizing composite materials and incorporating stiffeners, the panels aim to achieve high strength-to-weight ratios, allowing for optimal load-carrying capacity while minimizing weight.

4. METHODOLOGY

Carbon fibers are high-strength, high-modulus synthetic fibers commonly used in composite materials to enhance their mechanical properties. These fibers are composed mostly of carbon atoms and are known for their exceptional strength-to-weight ratio, stiffness, and resistance to temperature and corrosion. Here are key aspects of carbon fibers

Figure 1: Carbon Fiber

Applying resin to carbon fiber is a crucial process in the production of carbon fiber-reinforced polymer (CFRP) composites. This process, known as impregnation, involves thoroughly saturating the carbon fiber with a resin matrix to create a material that combines the strength and lightweight properties

Figure 2: Applying Resin

.Apply a Thin Layer: Using a soft, lint-free cloth or sponge, apply a thin, even layer of wax to the surface of the mold. Avoid applying too much wax, as it can lead to a buildup that might be difficult to polish and may affect the quality of the finish.

Figure 3: Applying Wax On Mould

Smoothing a mold surface with putty is a common practice in composite manufacturing, particularly when creating composite parts such as fiberglass or carbon fiber components. The process involves using putty to fill imperfections, irregularities, or surface defects on the mold, ensuring that the finished composite parts have a smooth and defect-free surface. Here's a general guide on how to smoothen a mold surface with putty

Figure 4: Mould Surface Smoothened With Putty

Applying a final peel ply layer in composite manufacturing is a step in the process that involves placing a specific type of fabric on top of the composite layup before the curing process. The final peel ply serves several purposes, including aiding in resin removal, providing a clean surface for secondary bonding, and creating a textured finish. Here's a general guide on placing the final peel ply in a composite fiber layup

Figure 5: Placing Final Peel Ply

Connecting a vacuum hose in the context of vacuum bagging in composite manufacturing involves linking the vacuum source, typically a vacuum pump, to the vacuum bag. This connection creates a negative pressure inside the bag, consolidating the layers of composite materials, removing air bubbles, and enhancing the overall quality of the composite part. Here are the steps to connect a vacuum hose for vacuum bagging

Figure 6: Vaccum Hose

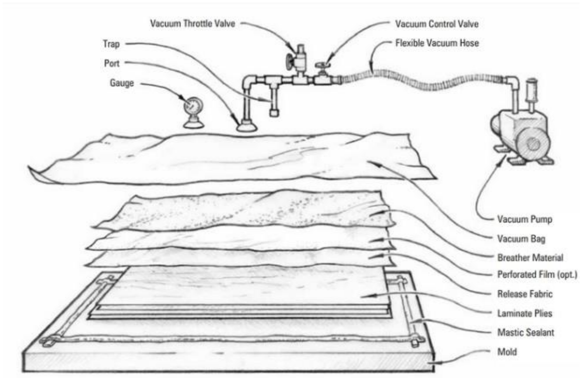


Figure7: Vaccum Bagging Method

Vacuum bagging (or vacuum bag laminating) is a clamping method that uses atmospheric pressure to hold the epoxy-coated components of a laminate in place until the epoxy cures. Modern room-temperature-cure epoxies like Entropy Resins eliminate the need for much of the sophisticated and expensive equipment that was required for vacuum bag laminating in the past. Thanks to epoxies like these, vacuum bagging is now a technique available to the average builder. With vacuum bagging, you can laminate a wide range of materials from traditional wood veneers to synthetic fibers and core materials.

Vacuum bagging uses atmospheric pressure as a clamp to hold laminate plies together. The laminate is sealed within an airtight envelope. The envelope may be an airtight mold on one side and an airtight bag on the other. When the bag is sealed, pressure on the outside and inside of this envelope is equal to atmospheric pressure: approximately 29 inches of mercury (Hg), or 14.7 psi. As a vacuum pump evacuates air from this envelope, the air pressure inside is reduced while air pressure outside of the envelope remains at 14.7 psi. Atmospheric pressure forces together the sides of the envelope and everything within the envelope, putting equal and even pressure over the surface of the envelope. The pressure differential between the inside and outside of the envelope determines the amount of clamping force on the laminate. Theoretically, the maximum possible pressure that can be exerted on the laminate, if it were possible to achieve a perfect vacuum and remove all of the air from the envelope, is one atmosphere, or 14.7 psi.

4. RESULTS AND DISCUSSION

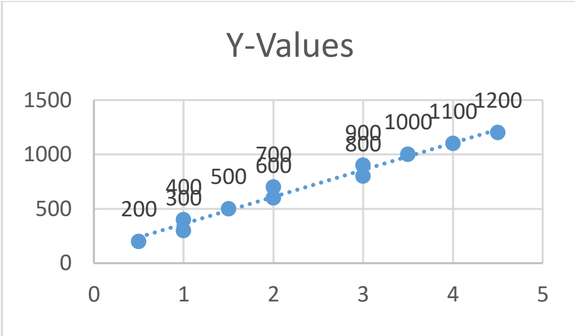
A buckling test is a mechanical test conducted to assess the structural stability and load-bearing capacity of a material or structural component when subjected to compressive loads. Buckling is a failure mode characterized by sudden, large deformations that occur when a compressive load exceeds the critical load for a given structure

Mild steel is a type of carbon steel with low carbon content, making it one of the most commonly used forms of carbon steel. It is known for its versatility, affordability, and ease of manufacturing.

MILD STEEL

WEIGHT IN KG	DEFLECTION IN MM
200	0.5
300	1.0
400	1.0
500	1.5
600	2.0
700	2.0
800	3.0
900	3.0
1000	3.5
1100	4.0
1200	4.5

Table 1: Buckling Test Of Mild Steel



Graph: Buckling Test Of Mild Steel Panel

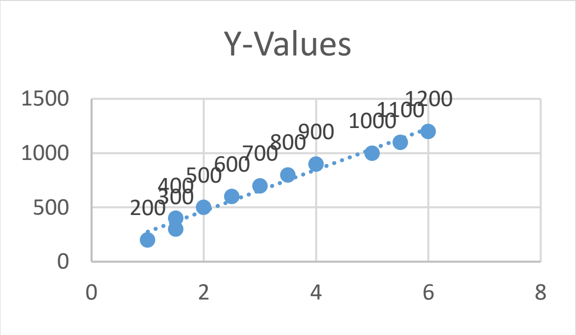
Conducting a buckling test on composite panels involves assessing how the panels behave under compressive loads, with a focus on their resistance to buckling. The following outlines a general procedure for conducting a buckling test on composite panels

COMPOSITE PANEL

WEIGHT IN KG	DEFLECTION IN MM
200	1.0
300	1.5
400	1.5
500	2.0
600	2.5
700	3.0
800	3.5
900	4.0
1000	5.0
1100	5.5
1200	6.0

Table 2: Buckling Test Of Composite Panel

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 08 | Aug - 2024 SJIF Rating: 8.448 ISSN: 2582-3930



Graph: Buckling Test Of Composite Panel

As a Result the Buckling Test Of Two Similar Dimensions Of Carbon Composite Panel and Mild Steel Panel, The Mild Steel Will Break At 4.5mm Deflection

The Composite Panel Will Resist Higher Load and Break At 6.0mm Deflection

5. CONCLUSION

The Buckling Test Of Two Similar Dimensions Of Carbon Composite Panel and Mild Steel Panel, The Mild Steel Will Break At 4.5mm Deflection

The Composite Panel Will Resist Higher Load and Break At 6.0mm Deflection

Composite stiffened panels find applications in various fields. In aerospace, they are used in aircraft fuselages, wings, and tail sections, contributing to weight reduction, fuel efficiency, and improved overall performance. In the automotive industry, stiffened panels are utilized in car bodies, chassis components, and interior structures, offering enhanced safety and rigidity. In marine applications, they are employed in boat hulls and decks, providing lightweight and corrosion-resistant solutions.

This study aims to explore and analyze the design, manufacturing, and performance of composite stiffened panels, contributing to the advancement and wider adoption of these lightweight, high-strength structural elements in various industries

REFERENCES

Frank E., Hermanutz F and Buchmeiser M. R. Carbon Fibers: Precursors, Manufacturing and Properties. Macromol. Mater. Eng. 2012;297: 493–501.

CrossRef

Schawaller D., Clauß B and Buchmeiser M. R. Ceramic Filament Fibers – A Review. Macromol. Mater. Eng. 2012:297:502–522.

Huang X. Fabrication and Properties of Carbon Fibers. Materials. 2009;2:2369-2403.

CrossRef

Bajaj P., Paliwal D. K.,Gupta A. K. Influence of metal ions on structure and properties of acrylic fibers. J. Appl. Polym. Sci. 1998;67:1647–1659.

CrossRef

Goodhew P. J., Clarke A. J., Bailey J. E. Review of fabrication and properties of carbon-fibers. Mater. Sci. Eng. 1975;17:3–30.

CrossRef

Ho C., Qian K. K and Bismarck H. A. Carbon Fiber: Surface Properties. Wiley Encyclopedia of Composites. 2011;1–11.