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ANALYSIS OF FRACTURE BEHAVIOUR COMPOSITE LAMINATES UTILIZING THE ANSYS SOFTWARE

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ABSTRACT

Composite laminates, composed of layers with different fiber orientations, are widely employed in engineering applications due to their lightweight and high-strength characteristics. However, the presence of delamination, or the separation of layers, can significantly compromise the structural integrity and performance of these laminates.

This study investigates the fracture behavior of delamination in composite laminates, focusing on both bi-directional and angle-ply configurations.

Keywords: Ø Composite laminates,
Ø Delamination,
Ø Fracture behavior,
Ø ANSYS, Bi-directional,
Ø Angle-ply, Finite Element, Analysis (FEA),

INTRODUCTION

DELAMINATION:

Delamination refers to the separation or detachment of layers in a material, typically in laminated structures.

Lamination involves bonding together multiple layers to create a composite material with enhanced properties.

These layers can be made of various materials such as metals, polymers, or composites, and are often combined to exploit the strengths of each component.

Delamination occurs when the adhesive or cohesive forces holding the layers together weaken or fail, leading to the formation of distinct layers or pockets within the material. This phenomenon is undesirable as it can compromise the structural

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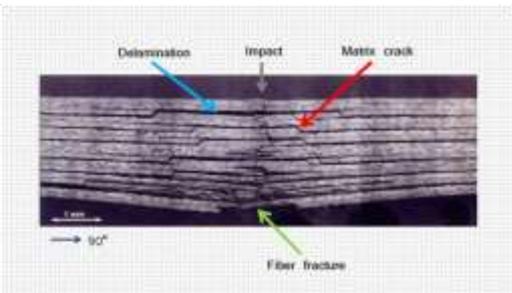
integrity, mechanical properties, and overall performance of the material.

DELAMINATION IN ANSYS SOFTWARE:

Delamination analysis is a crucial aspect of simulating and understanding the behavior of laminated composite structures using engineering simulation software like ANSYS.

ANSYS offers powerful tools for finite element analysis (FEA) that enable engineers to model, simulate, and analyze the effects of delamination in composite materials.

Delamination analysis in ANSYS involves studying the separation or detachment of layers within laminated structures, which is essential for predicting structural integrity and ensuring the reliability of components.

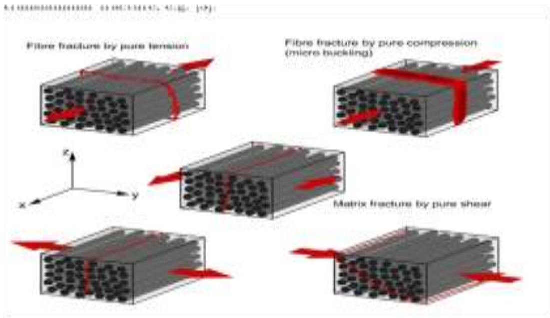


TYPE OF COMPOSITE LAMINATES:

Composite laminates are materials made by stacking multiple layers of different materials to create a structure with enhanced properties. The arrangement and orientation of these layers significantly influence the mechanical, thermal, and structural characteristics of the composite. Here are some common types of composite laminates:

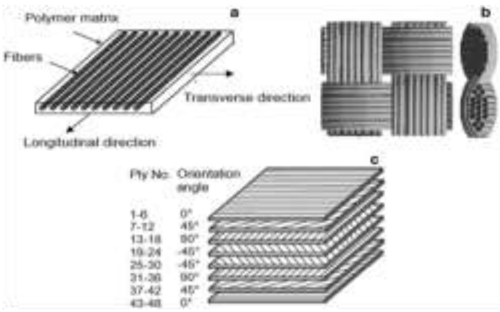
UNIDIRECTIONAL LAMINATES:

the sequence and orientation of the layers are identical on one side of the central plane in specific axis.



BIDIRECTIONAL LAMINATES:

Have different layer sequences or fiber orientations on either side of the central plane. These laminates are used when the loading conditions or requirements differ between the top and bottom layers.



CROSS PLY LAMINATES:

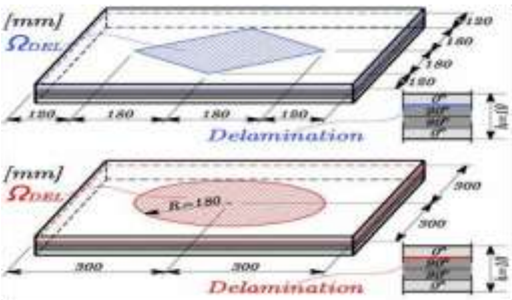
Cross-ply laminates, also known as 0/90 laminates, consist of alternating layers oriented at 0° and 90°.

This configuration alternates between layers aligned parallel (0 degrees) and perpendicular (90 degrees) to the main axis

This arrangement provides high stiffness in the axial direction but may be prone to delamination in certain loading conditions.

They are commonly used in the construction of thin-walled structures, such as panels and shells, where the combination of stiffness in different directions is crucial

Cross-ply laminates can exhibit good thermal stability due to the alternating fiber orientations. This property makes them suitable for applications where resistance to temperature variations is important.



ANGLE PLY LAMINATES:

Angle-ply laminates consist of layers oriented at a specific angle relative to the primary axis. The angle can vary depending on the requirements of the application. Common angles include 0°, 45°, and 90° plies

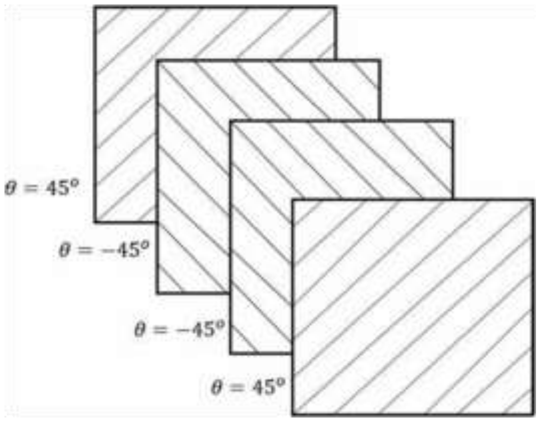
Angle-ply laminates involve arranging these layers at specific angles relative to the primary axis of the material. Here are some aspects to consider regarding angle-ply laminates in composite materials

Common angles include ±45 degrees, ±30 degrees, or other specified angles.

The interlacing of fibers at different angles helps prevent crack propagation through the thickness of the material.

angle-ply laminates are a versatile and valuable component in the field of composite materials.

Their ability to provide customized mechanical properties and resistance to various types of stresses makes them suitable for a wide range of applications in industries where lightweight, high-strength materials are crucial



TYPES OF COMPOSITE LAMINATES MATERIALS:

Carbon Fiber Reinforced Polymer (CFRP):

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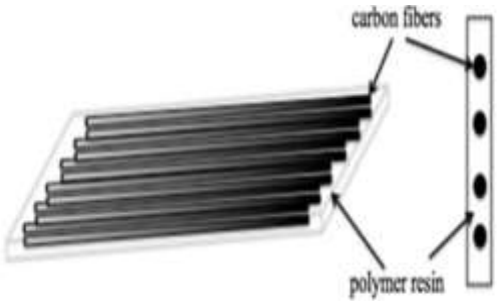
Advantages:

- Exceptional strength-to-weight ratio.
- High stiffness and low thermal expansion.
- Excellent fatigue resistance.

Widely used in aerospace, automotive, and sports

Limitations:

- High cost compared to other fibers.
- Susceptible to impact damage



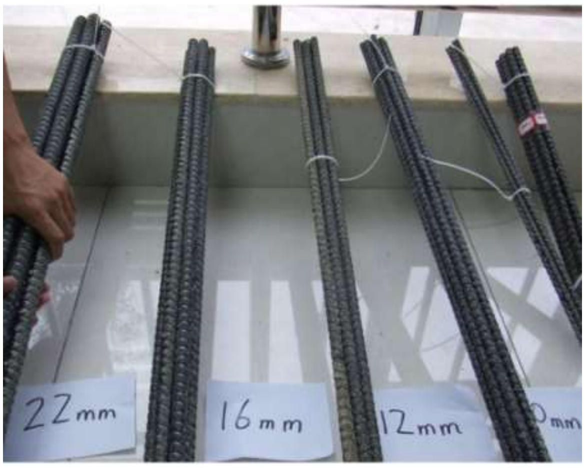
Glass Fiber Reinforced Polymer (GFRP):

- Advantages:
  - Cost-effective.
  - Good strength and stiffness.
  - Electrical insulation properties.
  - Commonly used in construction, marine, and automotive.
- Limitations:
- Lower strength compared to carbon fiber.

Susceptible to moisture absorption.

Basalt Fiber Reinforced Polymer:

- Advantages:
- High-temperature stability.
- Good resistance to acids and alkalis.
- Used in applications requiring fire resistance.
- Limitations:
- Limited availability compared to other fibers.
- Moderate strength properties.



Natural Fiber Reinforced Composites (e.g., Flax, Hemp):

- Advantages:
  - Renewable and sustainable.
- Lower environmental impact.
- Used in automotive interiors, consumer goods.
- Limitations:
  - Lower strength compared to synthetic fibers.
- Susceptible to moisture absorption.

AIM AND OBJECTIVES:

AIM:

The primary aim for delamination analysis in composite laminates using ANSYS software is to simulate and understand the behavior of laminated structures when subjected to loading conditions that may lead to the initiation and growth of delamination

This research is to meticulously explore the onset and progression of delamination within composite laminates when subjected to diverse loading scenarios.

The scope of this study encompasses a thorough examination of delamination as a failure mechanism, where the material splits into multiple layers, and an analysis of various laminate configurations such as bidirectional and angle-ply laminates.

OBJECTIVES:

The objectives of delamination analysis in composite laminates, specifically bidirectional laminates and angle-ply laminates, using ANSYS software, are centered around understanding and predicting the behavior of laminated structures when subjected to loading conditions that may lead to the initiation and propagation of delamination the critical loading conditions and locations where delamination is likely to initiate in the composite laminate structure and the growth of delamination cracks over time under various loading scenarios, including tension, compression, and shear.

Identify failure criteria and failure mechanisms specific to bidirectional and angle-ply laminates.

Use simulation results to optimize the

design of bidirectional and angle-ply laminates to minimize the risk of delamination

Determine the most influential parameters affecting the delamination behavior in bidirectional and angle-ply laminates

Develop strategies to mitigate the risk of delamination in bidirectional and angle-ply laminates

By using ANSYS software can make informed decisions in the design and optimization of bidirectional

and angle-ply laminates, ensuring their structural reliability and performance in practical

Literature review

JOURNAL SOURCE: ELSEVIER

[1] PAPER TITLE: fracture behavior of delaminated in cross ply laminated composites and unidirectional laminates

YEAR OF PUBLICATION: 2022 december

In this the investigation done on cross ply and unidirectional composites.

To this end, the load-displacement curve of the [05/90/06] stacking sequence is predicted by including hardening mechanisms such as zigzag crack growth, fiber bridging, and adhesion between fibers and resin in the FEM analysis

As the fibers are pulled out of the matrix during loading, energy is dissipated, so a UEL subroutine has also been used to implement this damage model

The results showed that this new approach could predict the load-displacement diagram of the DCB sample with the 0//90 interface with acceptable accuracy

[2] JOURNAL SOURCE: IJE TRANSACTIONS

PAPER TITLE: Fracture Behavior under the Effect of Cross-ply and Angle-ply Arrangement of FRP Composite Laminate Subjected to Central Circular Cut-out with Mechanical and Thermal Loading Conditions

YEAR OF PUBLICATION: April 2021

In this component are subjected to various thermal and mechanical loading conditions.

The present investigation is based on ANSYS analysis for finding the strain energy release rate (SERR) value using Virtual Crack Closure Technique (VCCT) to understand the fracture behavior of the composite lamina.

The angle-ply shows less SERR in mode I & II while cross-ply shows less SERR in mode III under the constant pressure loading conditions

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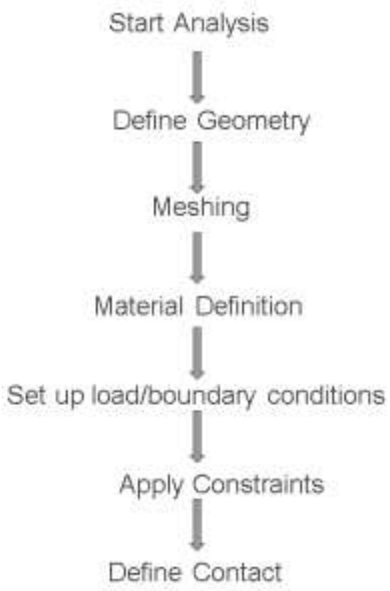
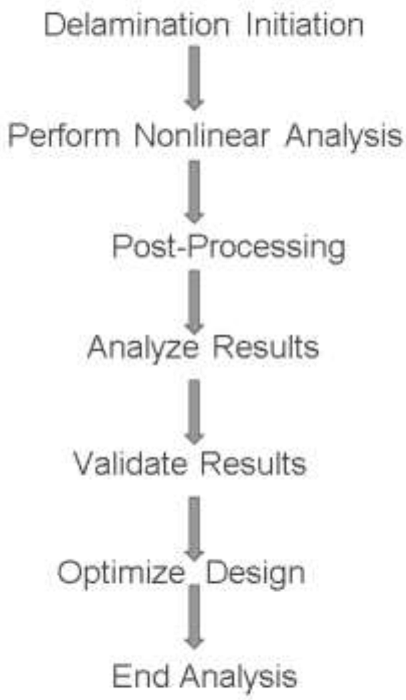
Mode II shows the maximum SERR in cross-ply compared to mode I and III for temperatures 30ºC, , 130 ºC and 180ºC. SERR for mixed-mode was found by considering the total mode of fracture and validation based on published literature for SERR due to the thermal load of mode I (GI) for different fiber layup configurations of the circular cut-out.

RESEARCH Methodology:

The research methodology employed involves the use of the Ansys simulation software to construct computational models of the composite laminates. These models are then subjected to a variety of loading conditions, and the resulting data are scrutinized to understand how delamination begins and evolves under these stresses.





This flowchart provides a structured approach to delamination analysis using ANSYS software, guiding users through the necessary steps for modeling, simulation, and post-processing. Keep in mind that the specific steps and parameters may vary based on the details of the analysis and the type of laminate being studied.

1 Start **Analysis:**

· Begin the delamination analysis process.

2. **Define Geometry:**

· Create or import the geometry of the bidirectional laminate structure into ANSYS.

3. **Meshing:**

· Generate a mesh that accurately represents the geometry, considering the layer orientations and stacking sequence.

4. **Material Definition:**

· Define the material properties for each layer in the bidirectional laminate, including elastic properties and fiber orientations.

5. **Set Up Load/Boundary Conditions:**

· Specify the loading conditions and boundary conditions based on the requirements of the analysis.

6. **Apply Constraints:**

· Apply constraints to simulate the real-world environment and ensure a realistic representation of the composite structure.

7. **Define Contact:**

· Define contact interfaces to model the interaction between adjacent layers and simulate delamination.

8. **Delamination Initiation:**

· Introduce initial defects or conditions to initiate delamination.

9. **Perform Nonlinear Analysis:**

· Conduct nonlinear analysis considering factors such as large deformations, material nonlinearity, and contact nonlinearities.

10. **Post-Processing:**

· Use ANSYS post-processing tools to analyse the simulation results.

11. **Analyze Results:**

· Evaluate the stress, strain, and deformation patterns to understand the behaviour of the bidirectional laminate.

12. **Validate Results:**

· Validate the simulation results against experimental or analytical data to ensure accuracy.

13. **Optimize Design:**

· Use insights from the analysis to optimize the design of the bidirectional laminate, making adjustments to minimize the risk of delamination.

14. **End Analysis:**

· Conclude the delamination analysis process

REQUIRED DATA COLLECTION:

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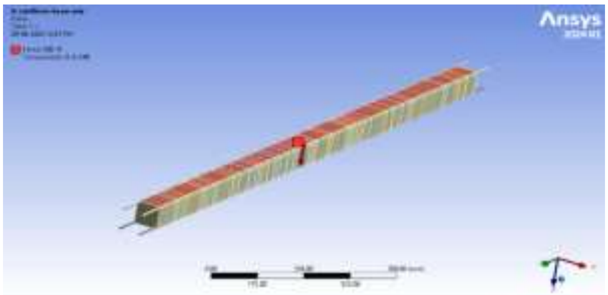
Data collection for this research is derived from the outcomes of the simulations conducted via Ansys.

This includes gathering information on stress distributions, points of fracture, and the response of different types of laminate structures when loaded

The configurations of particular interest noted in the research are bidirectional laminates, which consist of fibers oriented in both longitudinal and transverse directions, and angle-ply laminates, which have fiber layers oriented at specific angles to augment strength across multiple directions.

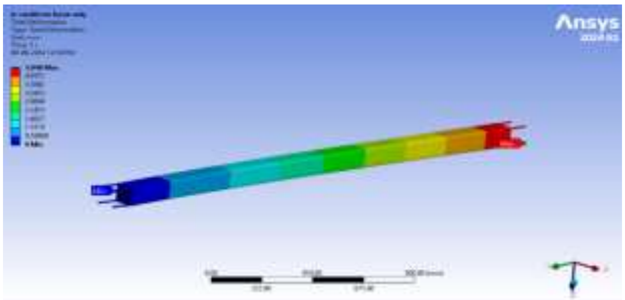
Analysis results:

Boundary conditions

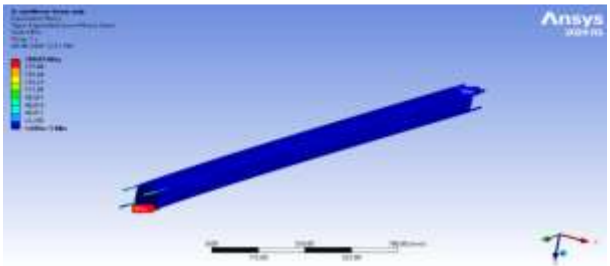


Cantilever beam:

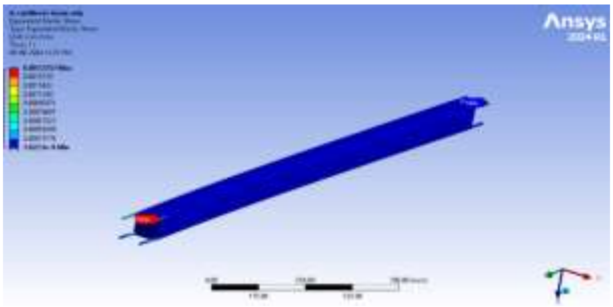
Deformation:



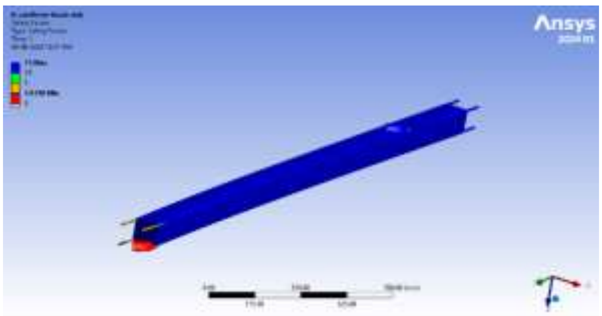
Stress



Strain



Safety factor:



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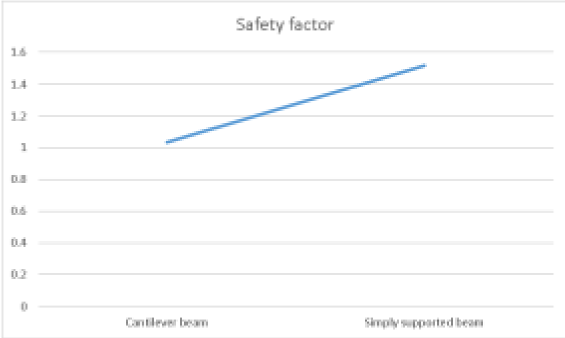
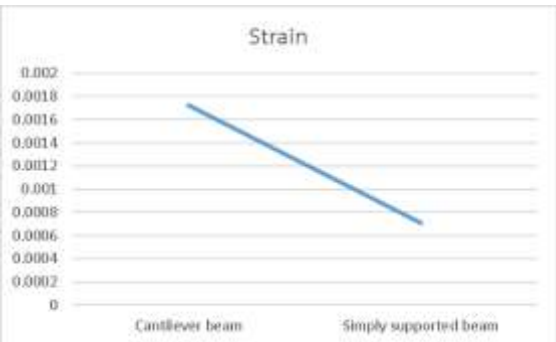
Differences between	Cantilever beam	Simply supported beam
Deformation (mm)	5.048	0.22974
Stress (Mpa)	199.85	136.21
Strain	0.0017257	0.00070932
Safety factor	1.0358	1.5197



Graphs : crack deflection curves



Beam with wrap - Basalt fiber Laminate

DIFFERENCE	CANTILVER BEAM	SIMPLY SUPPOERTED BEAM
DEFROMATIOM (mm)	4.4556	0.20637
Stress (Mpa)	205.95	101.04
Strain	0.0020865	0.0006362
Safety factor	1.0051	2.0487

Crack deflection curves (cantilever & simply supported)

Graphs:

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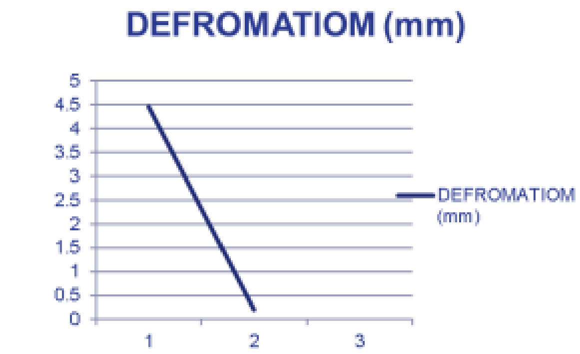
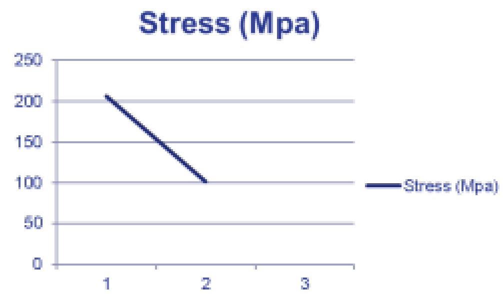




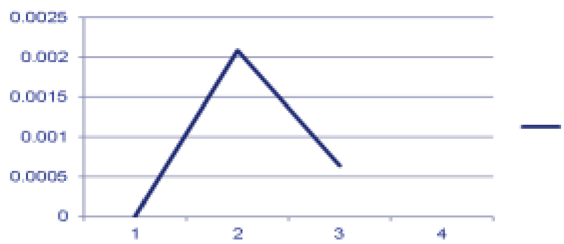
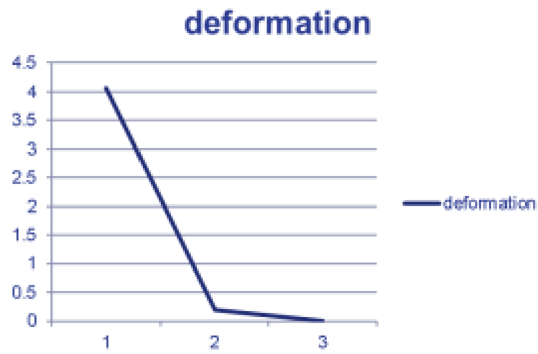


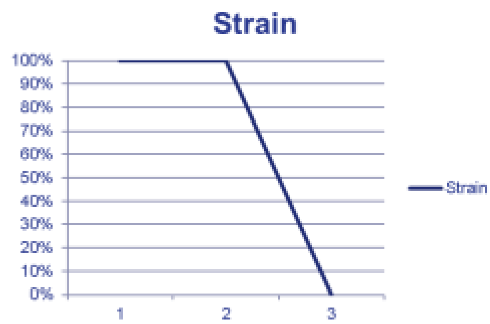
Table: carbon fiber reinforcement wrap

Graphs: Results (Cantilever beam and simply supported Beam)

Results	Cantilever beam	Simply supported beam
deformation	4.0681	0.19343
Strain	0.0021793	0.00062462
Stress	209.81	80.069
Safety factor	0.98662	2.324

Crack deflection curves (cantilever & simply supported)





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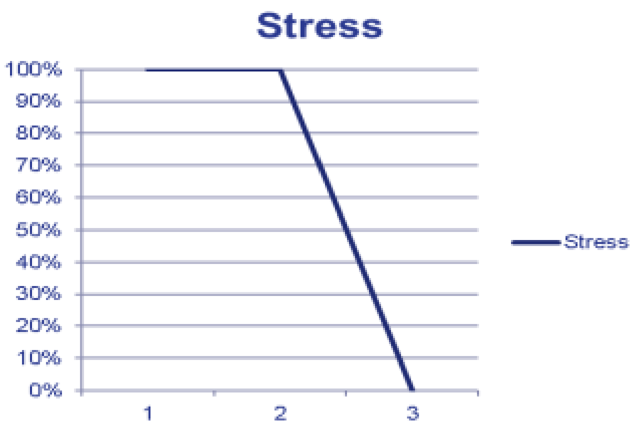

Conclusion

This investigative approach serves to enhance our understanding of behavior of composite laminates such as bi- directional and angle ply laminates , their mode of failures in different loading loadings , fracture parameters , stress & strain the effectiveness of simulation software like Ansys in predicting and analyzing such behaviors.

This research leverages ANSYS software to conduct a thorough investigation into the fracture behavior of delamination in bi-directional and angle-ply composite laminates.

The outcomes of this study can inform the design and stress strain behavior of wraps, of laminates for enhancing the structural integrity of composite materials in engineering applications.

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