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Materials Today: Proceedings 5 (2018) 5984–5992

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ICMPC 2017

Performance Analysis of Ply Orientation in Composite Laminates

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Abstract

With advancement in Material Sciences new types of materials are being invented and researched every day. Composite materials are globally used in aircraft design to decrease emissions and significant weight reduction. Advanced composite materials, which are usually continuous fibers (mostly carbon and glass) within a polymer matrix provide superior material properties than metals and enable lighter structural designs to be achieved in aerospace applications. In recent years, advanced composites have replaced traditional structural materials in aircrafts to a significant extent (e.g. Boeing 787, Airbus A350, with more than 50% composites by weight. The evaluation technique generally involves the implementation of ANSYS & MATLAB softwares that help in designing, drafting, and analysis. The scope of this paper is to highlight the researches done in composite laminates, new fibers and resins and to create future applications for composites. Eco-friendly resins will replace recycled plastics and bio-based polymers by composites. The present paper entitled “Performance Analysis of Ply Orientation in Composite Laminates” is the work done to perform the analysis on CFRP laminate with in-plane loading condition. In this research the mathematical calculation of determining the failure criteria of the laminate with ply orientation of [90/0/0/-45/+45]s is done by writing stress program on MATLAB and further analysis is performed using ANSYS. After obtaining both the results the design is validated.

*Keywords:*Composites laminates; CFRP; ply orientations; analysis; Matlab; ANSYS.

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2214-7853

Nomenclature

S	Symmetric
K	Kevlar
C	Carbon
G	Glass
T	Total

1.Introduction

The word composite in the term composite material signifies that two or more materials are combined on a macroscopic scale to form a third useful third material. The key is the macroscopic examination of a material wherein the components can be identifies by the naked eye. Different materials can be combined on a macroscopic scale, such as in alloying of metals, but the resulting material is, for all practical purposes, macroscopically homogeneous i.e., the components cannot be distinguished by the naked eye and act together. The advantage of composite materials is that, if well designed, they usually exhibit the best qualities of their components or constituents and often some qualities that neither constituent possesses.

1.1. Carbon fiber reinforced polymers

Laminated composite materials consist of layers of at least two different materials that are bonded together. Lamination is used to combine the best aspects of a constituent layers and bonding material in order to achieve a more useful material. In our research, Carbon Epoxy or Carbon Fiber Reinforced Polymers have been used. CFRP consists of Carbon fibers which are the reinforcement and the epoxy resin matrix, to bind the reinforcements together. It is a type of Particulate Composite Material.

1.2. Different types of laminate sequences

Two or more unidirectional laminates or a ply stacked together at various orientations is called Laminate. The plies can be of various thicknesses and consists of different or same materials as shown in below Table 1.

In our research we have used $[90/0/0/-45/+45]_S$sequence.

Table 1. Laminate stacking sequence.

Example	Laminate Stacking Sequence
Unidirectional	$[0/0/0/0/0/0] = [0_6]$
Cross-ply symmetric	$[0/90/0/90/0] = [0/90]_S$
Angle-ply symmetric	$[45/-45/-45/45] = [45/-45]_S = [\pm 45]_S$
Angle-ply asymmetric	$[30/-30/30/-30/30/-30/30/-30] = [30/-30] = [\pm 30]_4$
Quasi isentropic	[0/45/-45/90]
Symmetric Quasi isentropic	$[0/45/-45/90/90/-45/45/0] = [0/\pm 45/90]_S$
Multidirectional	[0/+45/30/-30/45]
Hybrid	$[0^k/0^k/45^c/-45^c/90^G/-45^c/45^c/0^k/0^k]_T = [0_2{}^k/\pm 45^c/90^G]_S$

1.3. Ply orientation and Failure

One of the fundamental advantages of laminates is their ability to adapt and control the orientation of fibres to best resist loadings. Plies contribute to the laminate resistance by orienting with respect to the loading direction. Fibres oriented at 45° can support the tension and –45° can support compression. In our research the laminate has 10 ply stacks and mid plane symmetry i.e. stacking of the plies on both sides starting from the mid-plane is identical. This is to limit inter laminar stresses as shown in below Fig 1 and Fig 2 (a) (b).