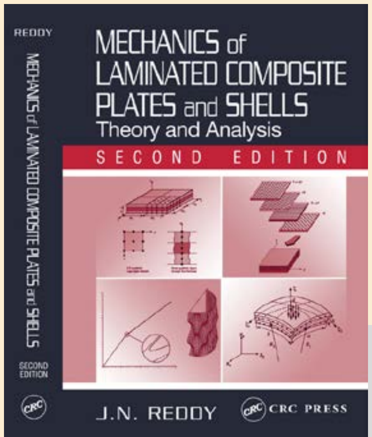
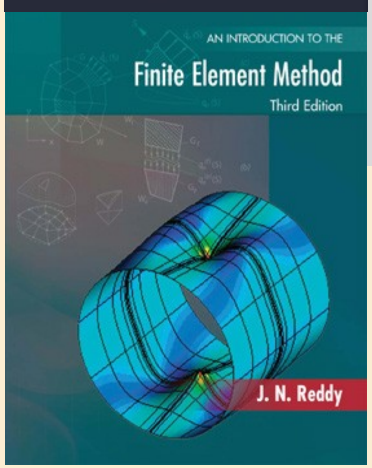
THEORY AND ANALYSIS OF LAMINATED COMPOSITE AND FUNCTINALLY GRADED BEAMS, PLATES, AND SHELLS





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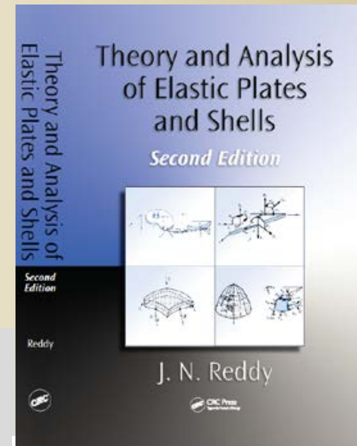
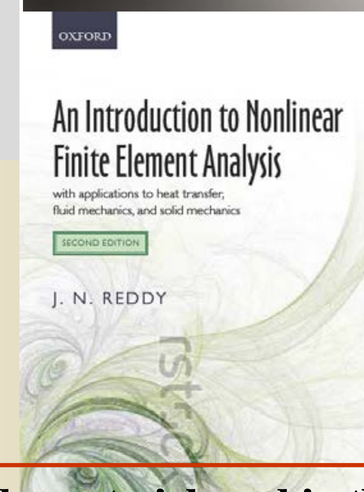




* **This document contains a copy of the overheads used in the course. Much of the material used in the course comes from the instructor's book, *Mechanics of Laminated Composite Plates and Shells* (2nd ed., CRC Press, 2004); other material comes from the research publications of the lecturer.**

THEORY AND ANALYSIS OF LAMINATED COMPOSITE AND FUNCTINALLY GRADED BEAMS AND PLATES

CONTENTS

COMPOSITE MATERIALS: General Introduction

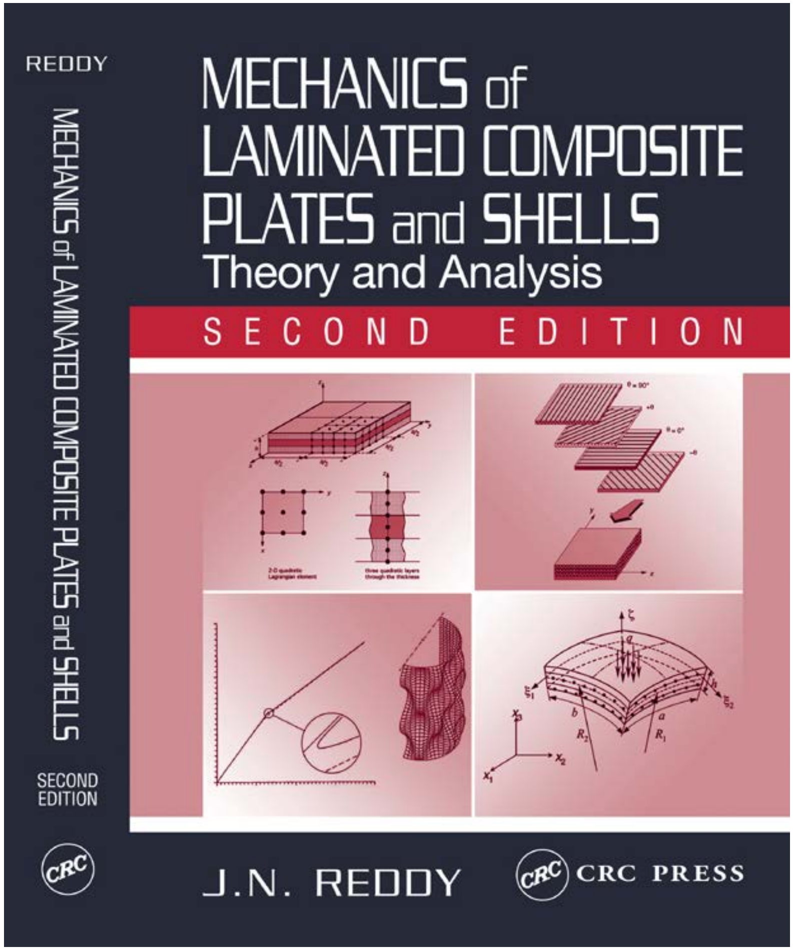
- Composite Materials - Definition
- The Big Picture
- The Role of Stress Analysis
- Classification of Composites
- Advantages and Disadvantages of Composites
- Use of Composite Materials in Aerospace Structures
- Study Areas in Composites
- Structural Analysis of Composite Structures
- Mechanical Characterization

NOTE:
Minor changes are made here and there to the viewgraphs without adding any major new material.

PRIMARY REFERENCE on mechanics of composite materials

J. N. Reddy, *Mechanics of Laminated Composite Plates and Shells*, 2nd ed., CRC Press, 2004 (introduction to the theory and analysis - analytical as well as FEM - of laminated composite plates and shells)

A list of papers authored by JN Reddy is provided at the end of this lecture notes. References to the works of many other authors can be found in *References* cited in the author's papers.

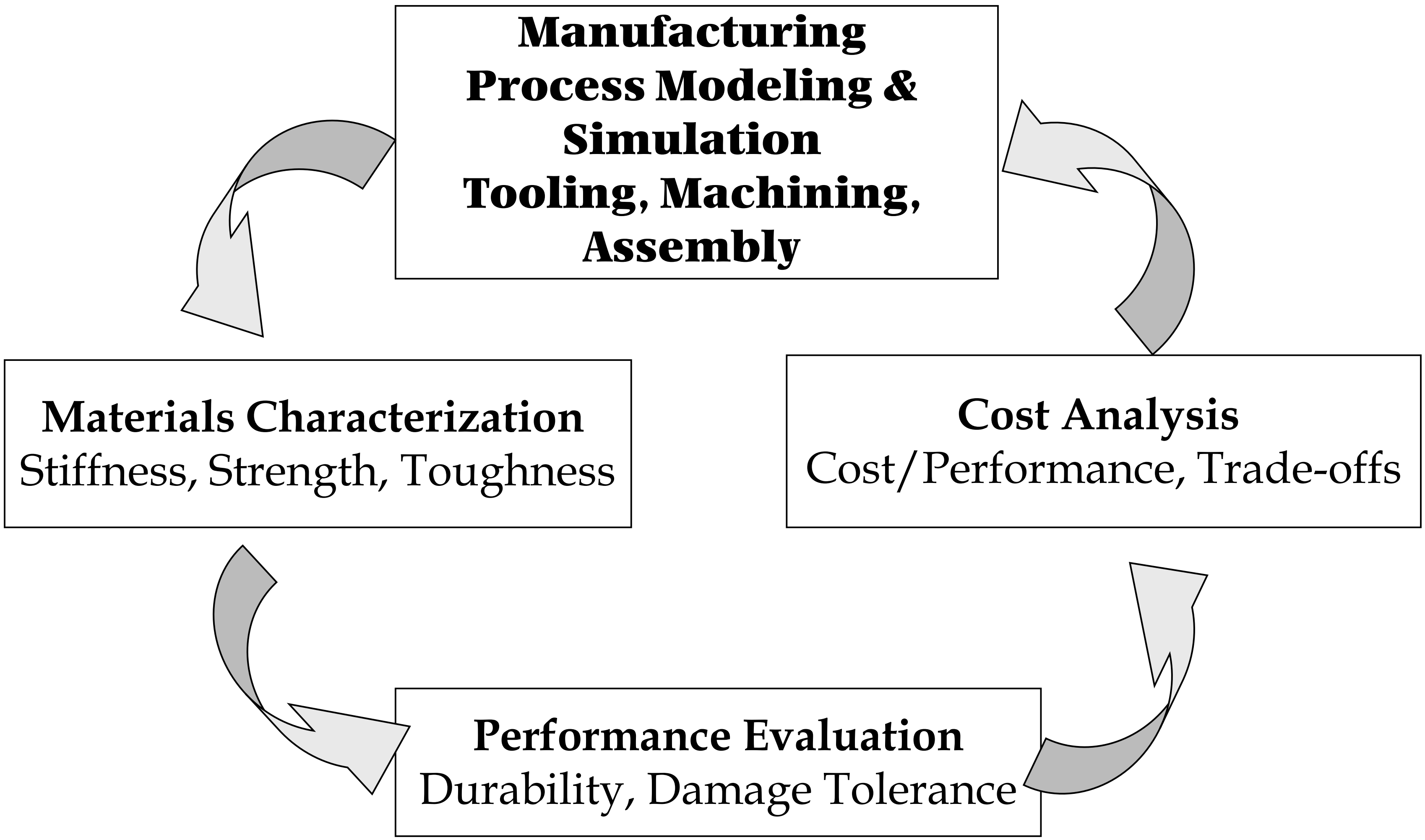


COMPOSITE MATERIALS-Definition

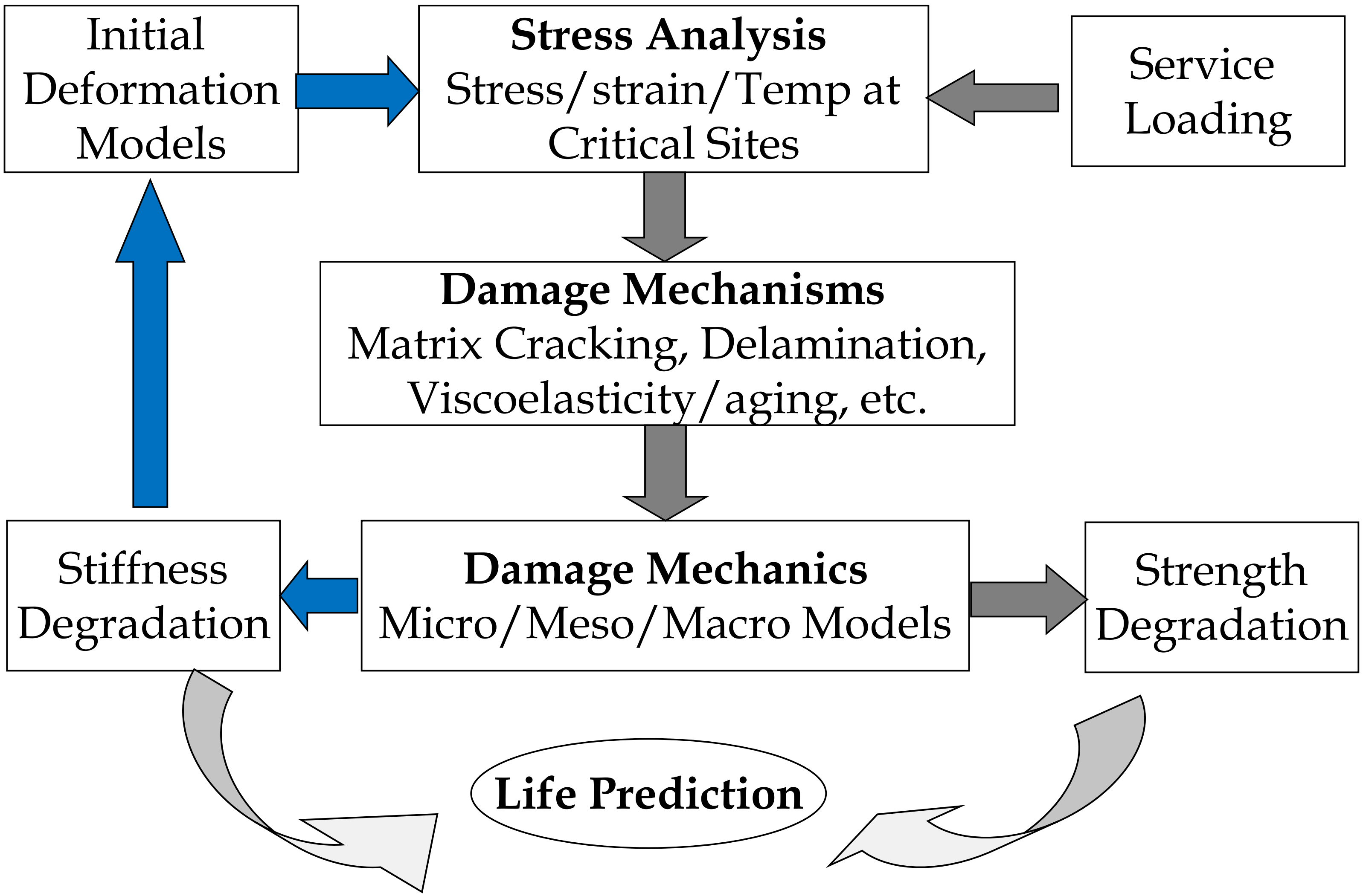
Definition: **Two or more materials combined on a *macroscopic* scale to form a useful third material**

Properties to be Improved: **Strength, stiffness, weight, fatigue life, wear resistance, thermal insulation, thermal conductivity, corrosion resistance, acoustical insulation, etc.**

THE BIG PICTURE



THE ROLE OF STRESS ANALYSIS



CLASSIFICATION OF COMPOSITE MATERIALS

Fibrous composites: Fibers in a matrix

Particulate composites: Particles in a matrix

Combinations of above: Reinforced fiber-reinforced composites

Woven composites

Braided composites

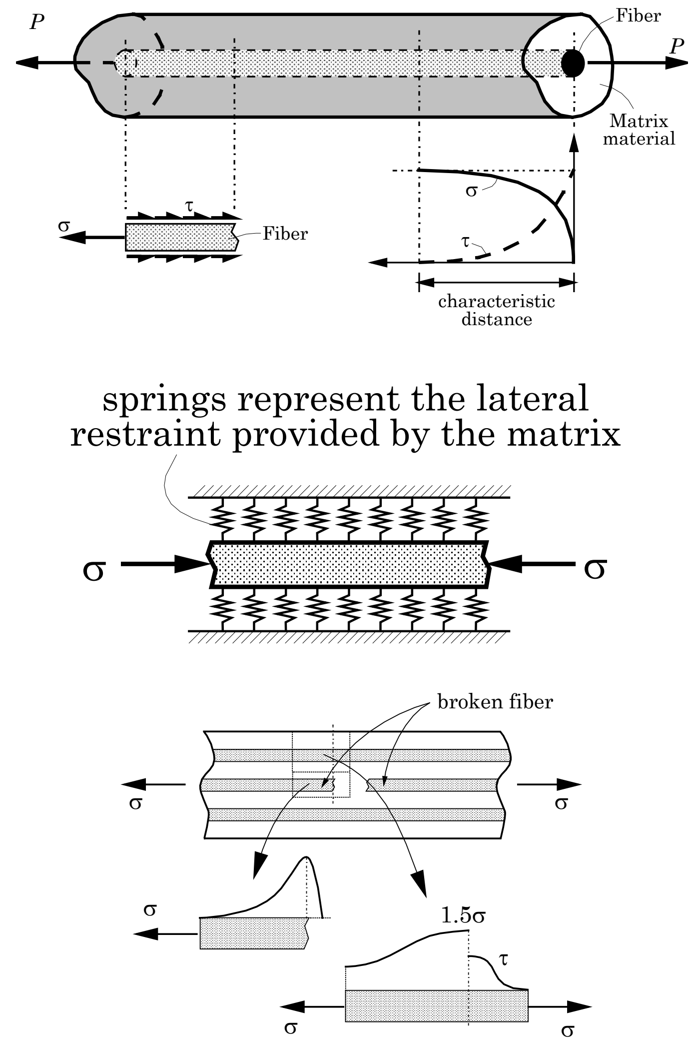
Laminated composites: Layers of various materials (nano-composites)

Fiber-reinforced Composite Materials: Constituents

Fiber: Load-carrying agent

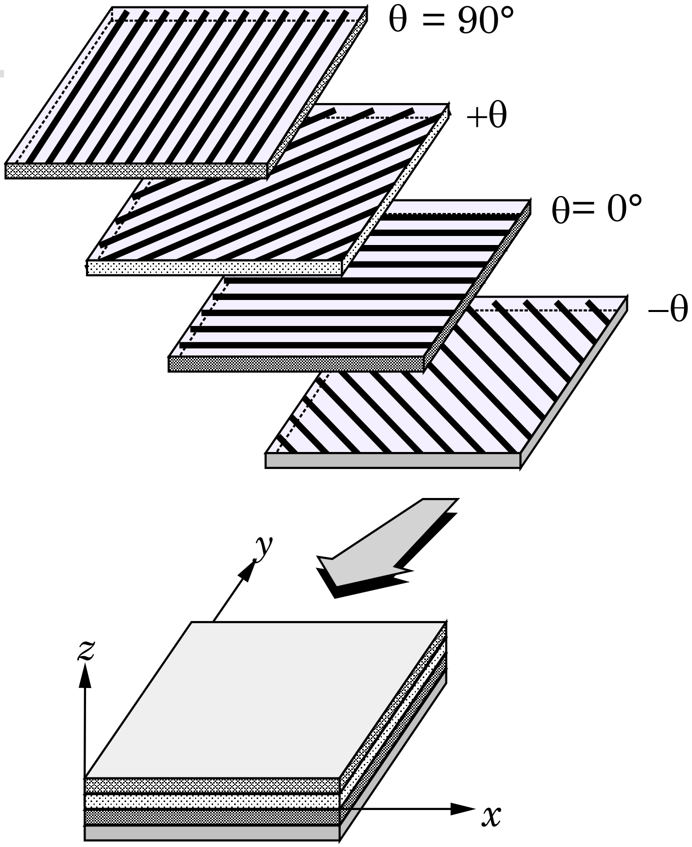
Matrix: Supports and protects fibers, and transfers load between broken fibers

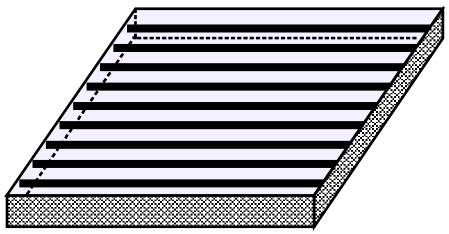
Lamina: Basic building block; flat or curved arrangement of unidirectional or woven fibers in a matrix



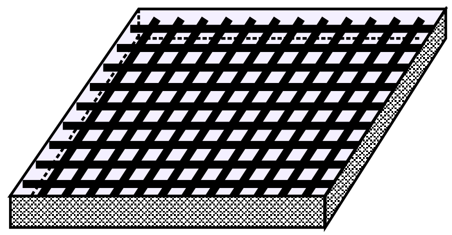
(c)

Classification of Composite Materials

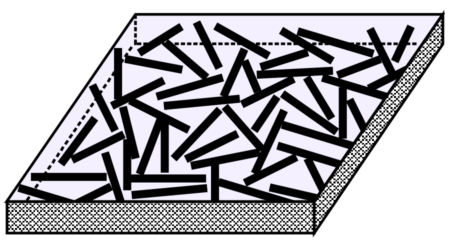




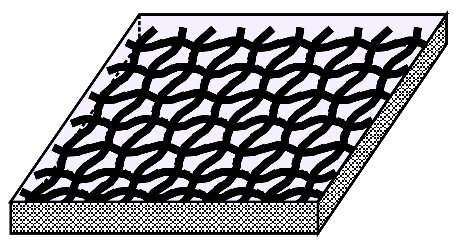
(a) Unidirectional



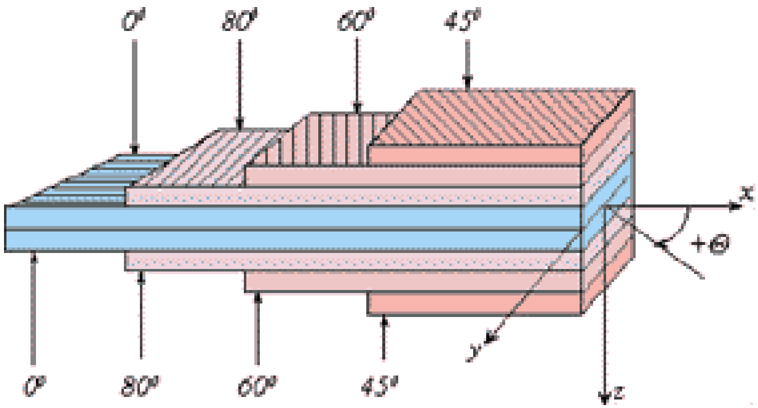
(b) Bi–directional



(c) Discontinuous fiber



(d) Woven



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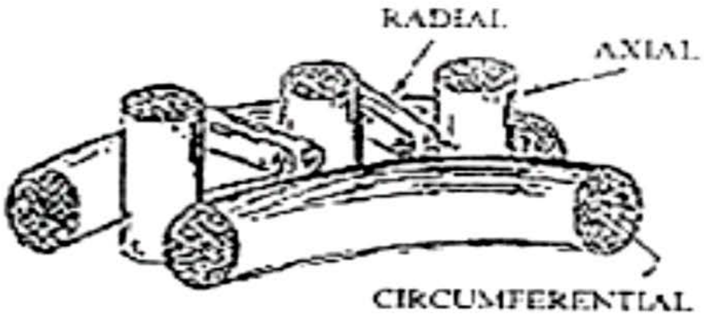
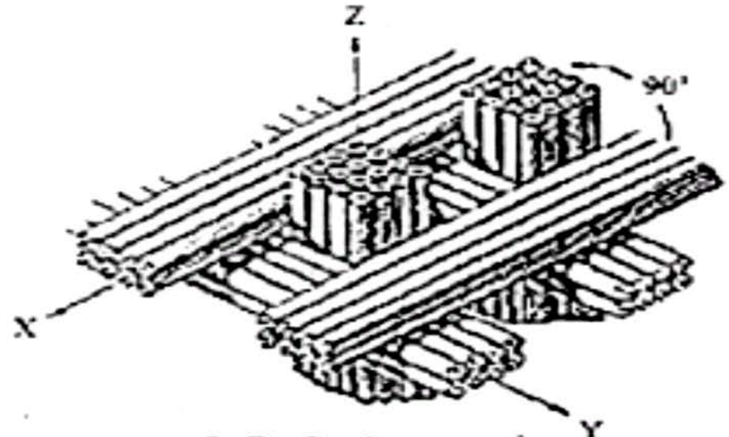
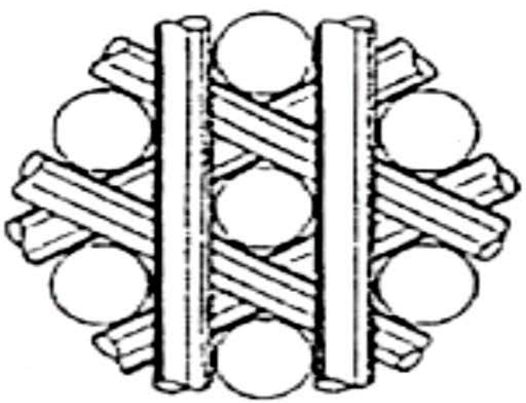
Woven Composites



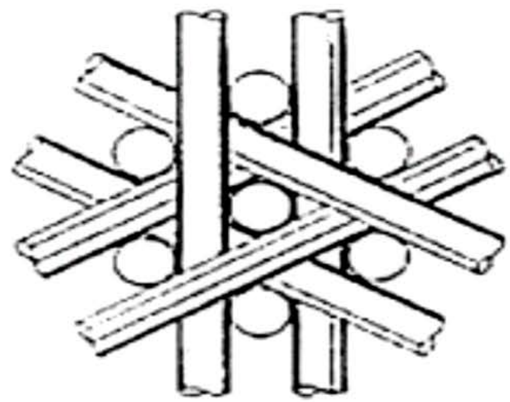
3-D Cylindrical



3-D Orthogonal



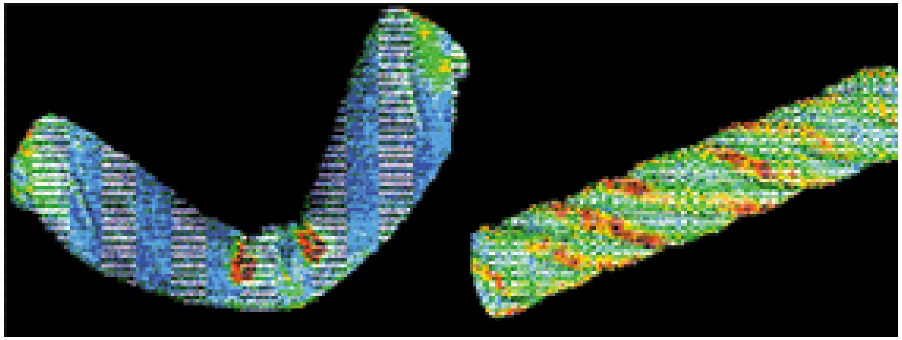
4-D In-Plane

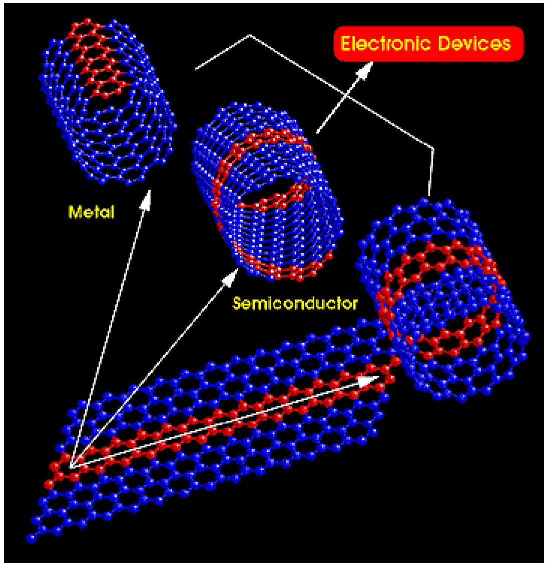


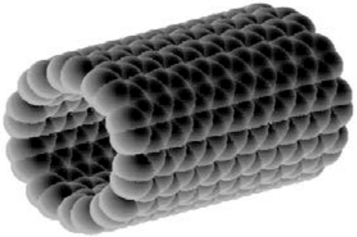
4-D Pyramidal

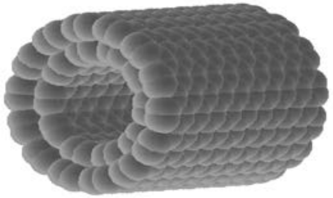
Nanocomposites: Carbon Nanotubes

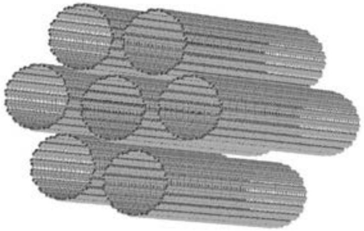
Carbon nanotubes can be viewed as a sheet of graphite that has been rolled in to a single tube. Carbon nanotubes can be single- or multi-walled.









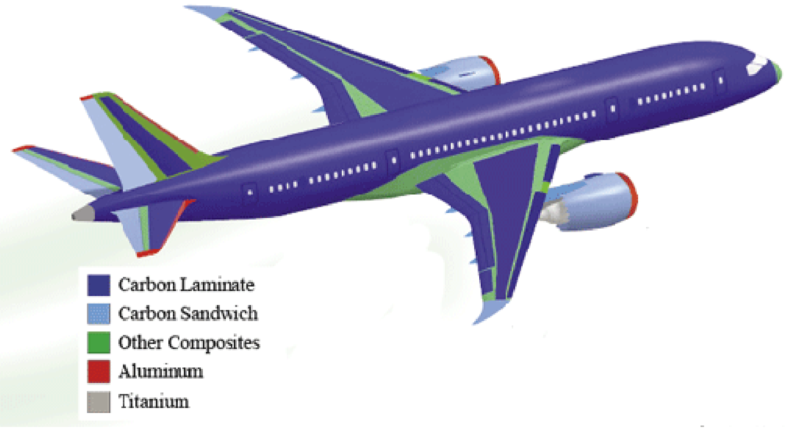


Advantages/Disadvantages of Composites

Advantages	*Disadvantages*
• Weight reduction • High strength or stiffness to weight ratio • Tailorable properties • Can tailor strength or stiffness in the load direction • Longer life (no corrosion) • Lower manufacturing costs because of less part count. • Inherent damping. • Increased (or decreased) thermal or electrical conductivity	• Cost of raw material and fabrication • Transverse properties may be weak. • Matrix is weak, low toughness • Reuse and disposal may be difficult • Difficult to attach. • Analysis is difficult. • Matrix subjected to environment degradation.

Composites in Aerospace Structures

Boeing 787 – more than 50% structure is made of composites



Composite components are approximately 15% of structural weight for civil aircraft.

For military aircrafts and helicopters, it is 40% of structural weight.

Earlier use of fibrous composites in aerospace are because of the potential for lighter structures as it affects fuel consumption, performance, and payload

Design requirements and objective for aerospace vehicles

Product	Structural item	Primary structural requirements	Primary design Objectives
Aircraft	Airframe	Compressive strength Damage tolerance Joint strength Durability	Minimum weight Maximum service
Helicopter	Rotor blades	Tensile strength Stiffness Fatigue life	Minimum weight Maximum service life
	Understructure	Stiffness Energy absorption	Minimum weight Crashworthiness

Design requirements and objective for aerospace and underwater vehicles

Product	Structural item	Primary structural requirements	Primary design Objectives
Rocket motor	Motor cases nozzles	Tensile strength Resistance to elevated temperature	Minimum weight Survivability at 2000 C
Satellite	Rotor blades	Stiffness Low thermal expansion	Minimum weight Dimensional stability
Marine (sub-mercibles)	Understructure	Compression strength and stability Joint integrity	Minimum weight Maximum depth

CHOICE OF COMPOSITE MATERIALS

Reason for use	Material selected	Application/driver
Lower inertia, less deflection	High strength carbon/graphite-epoxy	Industrial rolls
Light weight, damage tolerance	High strength carbon/graphite, hybrids, epoxy	Trucks and buses to reduce environment pollutions
More reproducible complex surface	High strength or high modulus carbon, graphite epoxy	High special aircraft