Introduction to Composite Materials and Structures

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Lecture 3
Introduction

Lecture Overview

- Fibers and whiskers
- Matrices
- Mechanical Behavior of Composites Materials
- Basic terminology

Fibers and Whiskers

- A ***fiber*** has:
  - High length-to-diameter ratio.
  - Its diameter approximates its crystal size.

- Modern composites exploit the fact that small scale samples of most of the materials are much stronger than bulk materials. Thus, thin *fibers* of glass are 200-500 times stronger than bulk glass.

- Several types of fibers are available commercially. Some of the more commonly used fibers are made from materials such as carbon, glass, Kevlar, steel, and other metals.

- Glass is the most popular fiber used in composites since it is relatively inexpensive. It comes in two principal varieties; E-glass, and S-glass. The latter is stronger than the former.

Fibers and Whiskers

- Fibers are significantly stronger than bulk materials because:
  - They have a far more “perfect” structure, i.e. their crystals are aligned along the fiber axis.
  - There are fewer internal defects, especially in direction normal to fiber orientation, and hence there are lesser number of dislocations.
- At larger scales, the degree of structural perfection within a material sample is far less that what is present at small (micro and nano) scales. For this reason fibers of several engineering materials are far more strong than their equivalent bulk material samples.

Fibers and Whiskers

- The following table lists bulk as well as fiber properties for different materials. It is seen from the table that the difference between bulk and fiber strengths is significant.

Table 2.1: Properties of Some Common Engineering Materials in Bulk and Fiber Forms

Fiber	Specific Gravity	Young's Modulus (GPa)	Bulk Tensile Strength (MPa)	Fiber Tensile Strength (MPa)
Aluminium	2.7	78	140-620	620
Titanium alloy/fiber	4.5	115	1040	1900
Steel	7.8	210	340-212	4100
E-Glass	2.54	72	70-210	3500
S-Glass	2.48	86	70-210	4600
Carbon	1.41	190	very low	2100-2500

Fibers and Whiskers

- ***Whiskers*** are similar in diameter to fibers, but in general, they are short and have low length-to-diameter ratios, barely exceeding a few hundreds.

- Thus, the difference in mechanical properties of a whisker vis-à-vis bulk material is even more pronounced. This is because the degree of perfection in whiskers is even higher vis-à-vis that in fibers.
  - Whiskers are produced by crystallizing materials on a very small scale.
  - Internal alignment within each whisker is extremely high.

Whiskers

- The following table lists bulk as well as whisker properties for different materials. It is seen from the table that the difference between bulk and whisker strengths is very significant.

Table 2.2: Properties of Some Common Engineering Materials in Bulk and Whisker Forms

Fiber	Bulk Tensile Strength (MPa)	Whisker Tensile Strength (MPa)
Alumina (Al_2O_3)	105-107	19000
Silicon Carbide	3440	11000
Copper	220	3000
Iron whisker v/s bulk steel	525-700	13000
Boron carbide	155	6700
Carbon	very low	21000

- Modern composites derive much of their desired properties by using fibers and whiskers as one of the constituent materials.

- Fibers made from carbon, E-glass, S-glass, and Kevlar are commonly used in modern composite structures.

Problem Set

- Explore different types of fiber materials. What fibers would you used with an objective to:
  - Improve thermal conductivity
  - Improve electrical conductivity
  - Improve mechanical strength
  - Improve toughness

What you learnt in this lecture?

- Fibers and whiskers
- Matrices
- Mechanical Behavior of Composites Materials
- Basic terminology