Mechanics of Composite Materials

CHAPTER 1.
Introduction

SangJoon Shin

School of Mechanical and Aerospace Engineering

Seoul National University

Outline

1. Introduction
2. Micromechanics
3. Ply Elasticity
4. Laminate Theory
5. Failure
6. Bending and Coupling
7. Thermal Stresses
8. Advanced Topics

- Builds on basis solid mechanics and structures. Goes intro anisotropic properties, matrix manipulation of stress & strain, laminated materials

1. Introduction

❖ What is a composite material?

- Generally, materials with 2 or more constituents combined by a physical process on a macroscopic scale
- Fibers on particles in a matrix
- Layers of dissimilar materials

❖ Why composite?

- Can achieve properties not possible with a monolithic (homogeneous) material
- Constituents have two different functions

  Reinforcement: Provides most of properties

  Matrix: Binds together reinforcement

1. Introduction

❖ Some Examples

Reinforcement	Matrix
Straw	Clay
Sand, Rock	Cement, Water
Cellulose	Legnin (wood)

❖ We care about advanced (aerospace) use

Reinforcement		Matrix
Fiber	Graphite	Polyester
	Boron	Epoxy
	Kevlar	Polyimids
	Glass	Thermoplastic
Chopped Fiber	SiC	Aluminum
	"	Titanium
Cloth		Carbon
Particles		Glass

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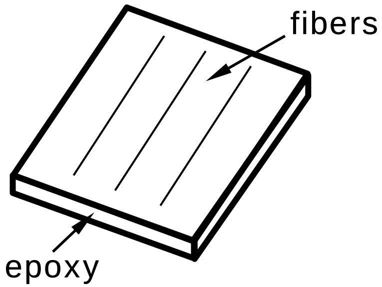
❖ **Will limit our attention to**

① Continuous fibers

② Collimated fibers:



Often comes in "prepreg" (preimpregnated) sheets

❖ **Why use composites?**

- Better specific properties
- Better specific stiffness, E/ρ
- Better specific strength, σ_{ult}/ρ

  for minimum weight structures

1. Introduction

❖ **Composites are light, low ρ**

Material	ρ (S.G)	E (GPa)	σ_{ult} (MPa)	E / ρ* (normalized on Al)	σ_{ult} / ρ* (normalized on Al)
Al 2024-T3	2.77	74	462	1.0	1.0
Steel 300M	7.84	200	1931	1.0	1.5
Gr/Ep	1.61	130	1661	3.0	6.2

❖ **Composites** - Less weight for same stiffness and strength

- Importance in Aerospace:

Range of A/C, $R = \frac{L}{D}\frac{V}{(SFC)}\ln\frac{W_0}{W_F}$ (Brequet Eq.)

Speed of Rocket, $V = V_E \ln\frac{W_0}{W_F}$ (Rocket Eq.)

(V_E: exhaust velocity)

where, W_0: gross weight / W_F: final weight

1. Introduction

- Less structural weight → { more range / speed, more payload }

  A/C: $300/lb payload

  Satellite: $10,000/lb

  Round world flight (Voyager)
  High speed civil transport
  Single – stage – orbit
  } use composites

1. Introduction

❖ Other advantage

- Tailoring : Pick fiber, matrix, arrangement to get properties you want
  (include zero coefficient of tension/extension, bending/torsion coupling, strength)
- Good fatigue life
- Good corrosion resistance
- Manufacture can be cheaper (molding, automatic process)
- Stealth (low radar response)

❖ Disadvantages

- Cost (materials, more steps now)
- Environmental effects (H_2O, impact, heating, space)
- Technological Risk
- Harden to Design