BMM1523/BHA1113
ENGINEERING MATERIALS

COMPOSITES

by
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Chapter Description

- **Aims**
  - To introduce the basic concept of composite materials
  - To understand the types of composites and its properties.

- **Expected Outcomes**
  - Student can classify the type of composite material
  - Student able to describe the properties of each composite materials

- **References**

1. William D. Callister and David G. Rethwisch. Materials science and enginnering: An Introduction, 9th Ed. Wiley, 2014.

Introduction of composite material

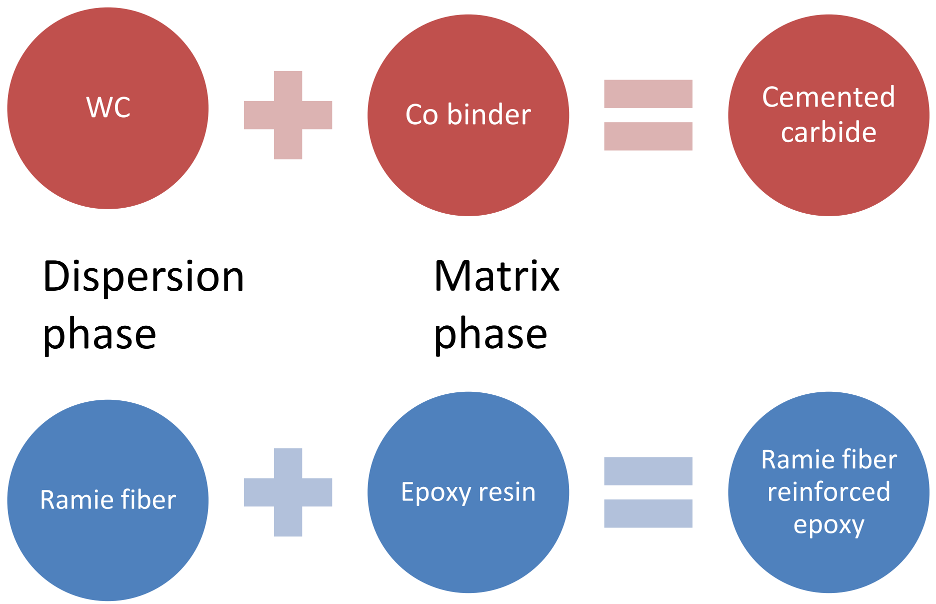
<u>Definition:</u>
Composite is a material system made up by mixture or combination between two or more material that consist of different composition and insoluble to each other.

Two phases of composite:
1) Dispersion phase
2) Matrix phase

- ❑ Dispersion (fiber) phase is a structure constituent. Dispersion phase carry loads along the length of fiber and provide strength and stiffness in one direction to the matrix material in the composite.

- ❑ Matrix phase is a continuous material constituent. Matrix bond the fibers together and to transfer loads between them

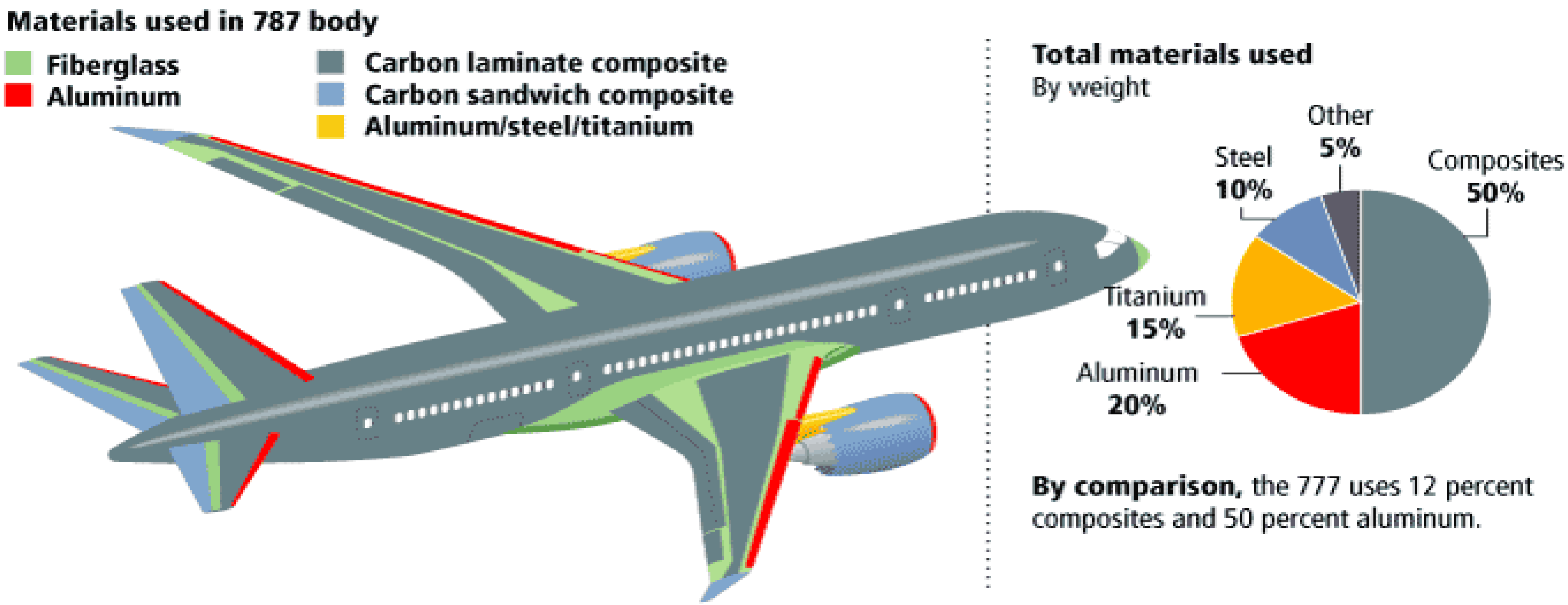
<u>Example:</u>



Advantages of composite material

- Corrosion and oxidation resistance
- Low cost of production
- Improved stiffness of material
- Better creep and fatigue strength is better
- Lower specific gravity
- Higher specific strength than metal
- Toughness improved

Application of composite material



Other application

- Automotive
- Marine
- Sport
- Structural/ infrastructure
- Wind power

Type of composite

Metal matrix composite (MMC)

Term:
Material have a metal as matrix material in composite

General Properties:
High strength and high toughness

Example:
Boron/ Aluminum composite

Ceramic metal composite (CMC)

Term:
Al_2O_3 and SiC imbedded with fibers

General properties:
High thermal resistance

Example:
aluminium–alumina composites

Polymer matrix composite (PMC)

Term:
Material have a polymer matrix (thermoset or thermoplastic) a matrix material in composite.

General properties:
Low weight, High strength

Example:
Fiber glass reinforced polyester composite

Detail of MMC

Specific area and application

- Graphite-Aluminum: Satellite, missile
- Boron-Magnesium: Antenna structure
- Silicon carbide-titanium: High temperature structure

Properties

- High modulus of elasticity, ductility and resistance to elevated temperature
- Heavier and difficult to process

Matrix

- Aluminum, lead, copper, magnesium

Fiber

- Graphite, boron, Alumina, Silicon carbide, Molybdenum, tungsten

Detail on CMC

Specific area of application

- Applied on the environment that requirement high temperature and significant corrosion resistance.
- Jet and automobile engine, cutting tool and pressure vessel

Properties

- Advantages: Strong, hardness, hot hardness, and compressive strength, low density and high stiffness. Retain strength up to 1700°C.
- Disadvantages: low toughness and bulk tensile strength, susceptibility to thermal cracking.

Matrix material

- Silicon carbides
- Silicon nitrides
- Aluminum oxide

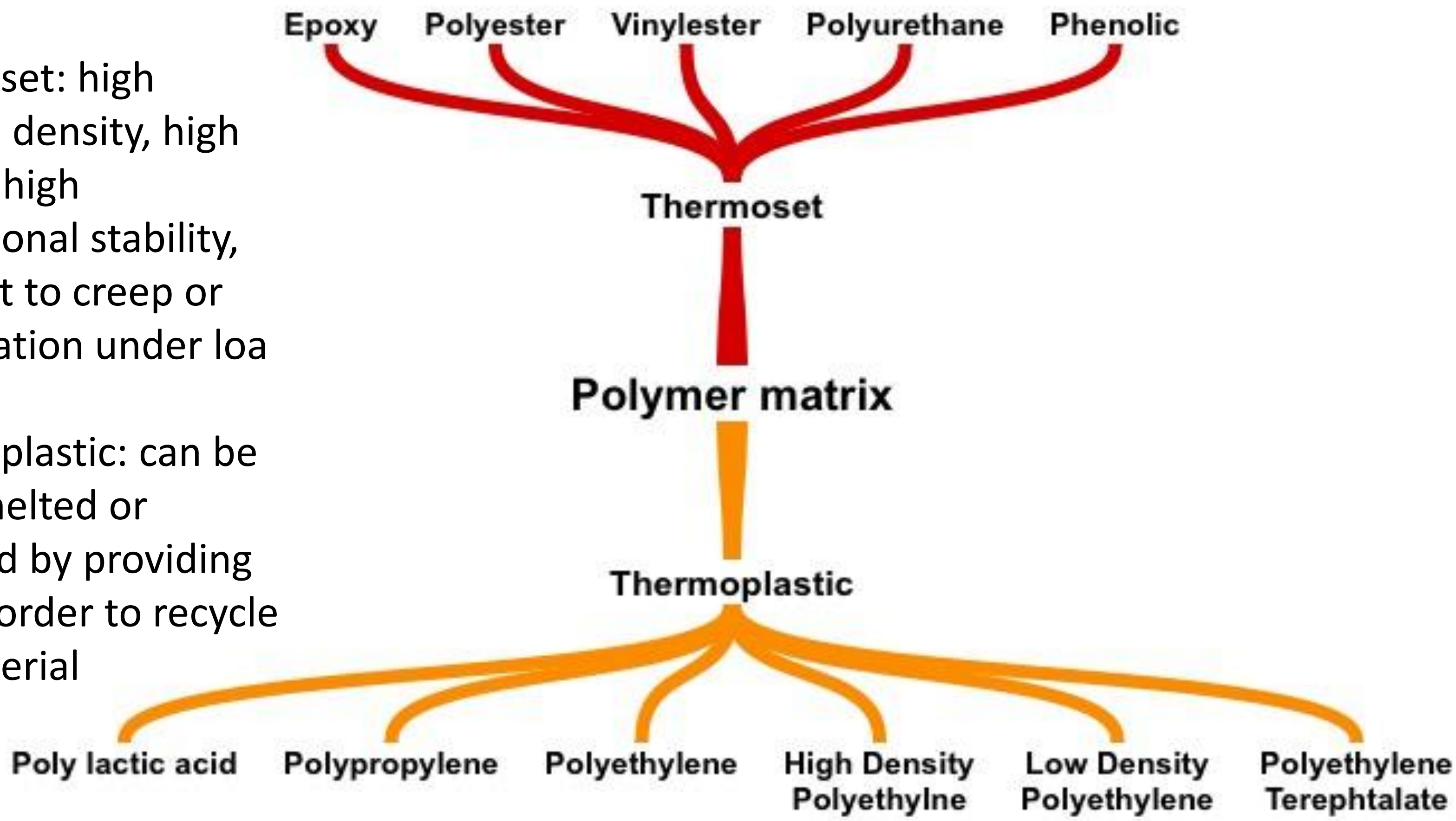
Fiber material

- Carbon
- Aluminum oxide

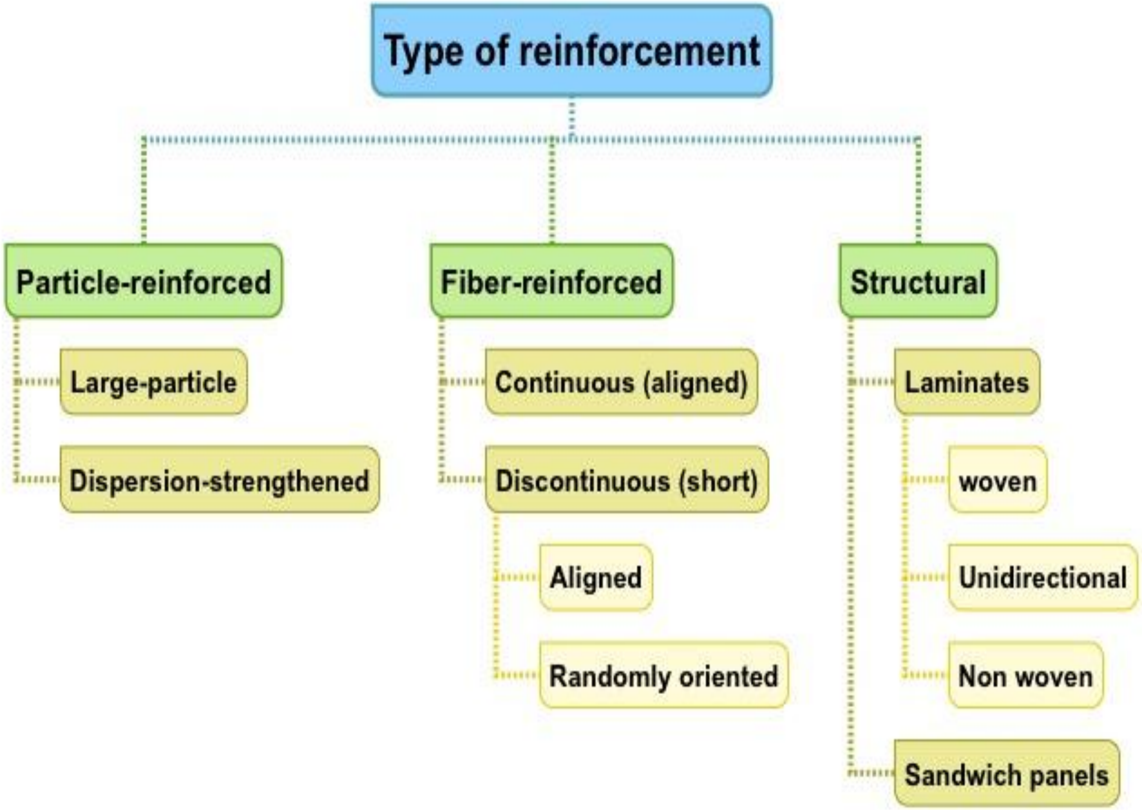
Detail on PMC : Polymer matrix

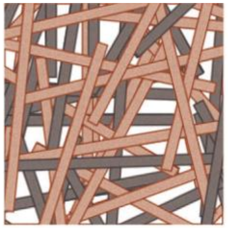
Thermoset: high thermal density, high rigidity, high dimensional stability, resistant to creep or deformation under loa

Thermoplastic: can be easily melted or softened by providing heat in order to recycle the material

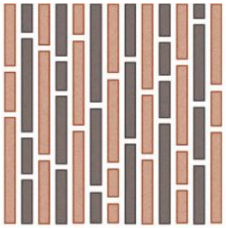


Detail on PMC: type of reinforcement



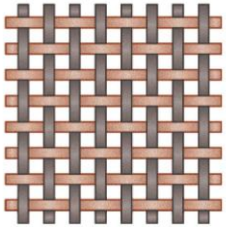


Discontinuous and randomly oriented



Discontinuous and aligned

Continuous and aligned



Fabric

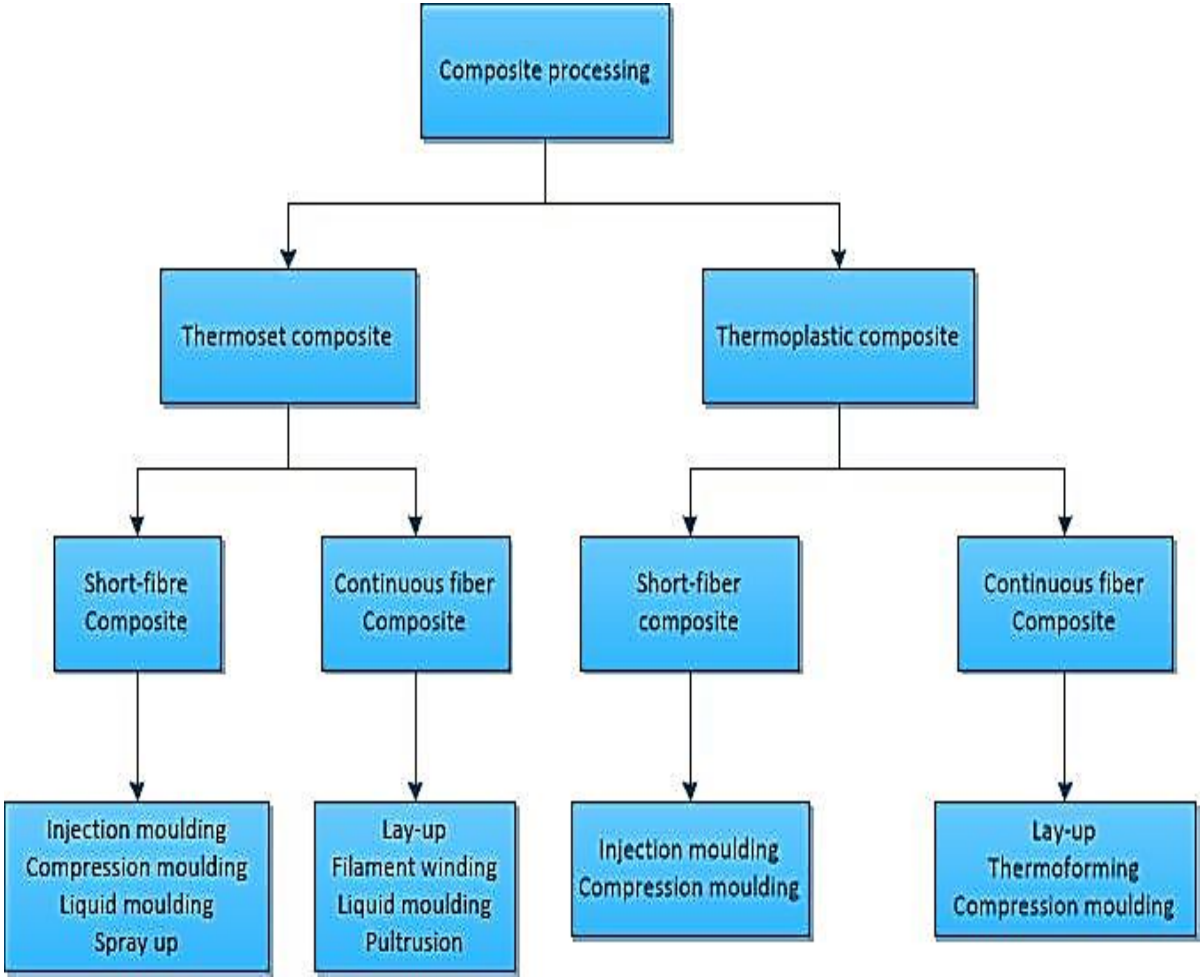
Mechanical performance: Structural>fiber-reinforced> particle-reinforced

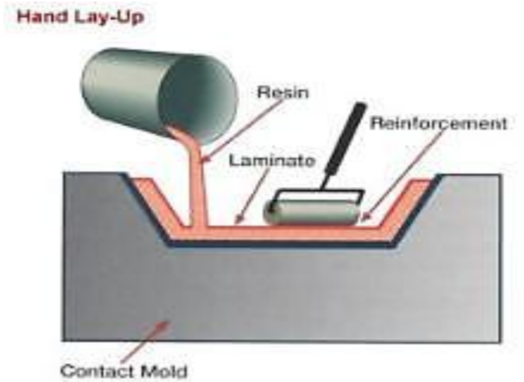
- **Fibre**
  - Synthetic
    - Organic fibre
      - Aramid/Kevlar
      - Polyethylene
      - Aromatic polyester
    - Inorganic fibre
      - Glass
      - Carbon
      - Boron
      - Silica carbide
  - Natural
    - Animal
      - Silk
      - Wool
      - Hair
    - Mineral
      - Asbestos
    - Cellulose/Lignocellulose
      - Bast
        - Jute
        - Flax
        - Hemp
        - Ramie
        - Kenaf
        - Roselle
        - Mesta
      - Leaf
        - Sisal
        - Banana
        - Abaca
        - PLAF
        - Henequen
        - Agave
        - Raphia
      - Seed
        - Kapok
        - Cotton
        - Loofah
        - Milk Weed
      - Fruit
        - Coir
        - Oil Palm
      - Wood
        - Soft Wood
        - Hard Wood
      - Stalk
        - Rice
        - Wheat
        - Barley
        - Maize
        - Oat
        - Rye
      - Grass/Reeds
        - Bamboo
        - Bagasse
        - Corn
        - Sabai
        - Rape
        - Esparto
        - Canary

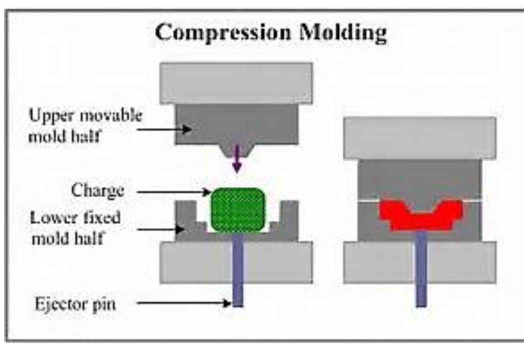
Mechanical properties of fibers (natural and synthetic)

	Fiber type	Diameter (μm)	Density (Kg/m^3)	Elongation at break (%)	Tensile Strength (MPa)	Modulus (GPa)
Bast fiber	Flax	-	1500	1.2-3.2	800-1500	60-80
	Jute	25-250	1300-1490	1.8	400-800	10-30
	Hemp	-	1480	1.6	550-900	70
	Kenaf	70-250	749	2.7-6.9	295	14
	Kudzu	-	--	-	130-418	-
	Okra	-	-	2	68-282	5.74-16.55
	Ramie	-	1550	2	400-938	44
	Bamboo	-	600-1100		140-230	11-17
	Roselle	-	800-700	5-8	147-184	2.76
Man-made	Carbon	8.2	-	-	-	-
	E-glass	15-25	2550	2.5-3.7	2000-3000	70-73
	S-glass	-	2000	4.6	4600	85

PMC detail: processing method



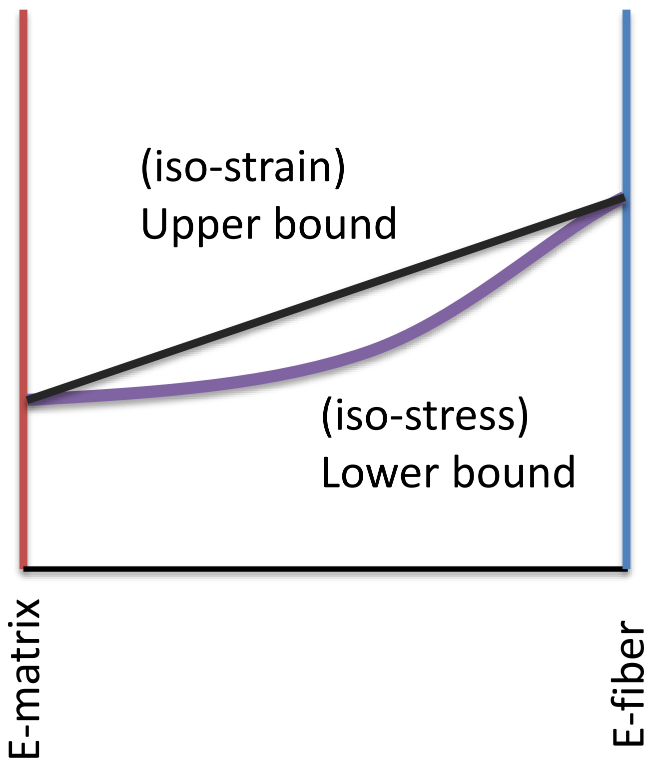




Detail on PMC: Rule of mixture

Purpose:
To predict the value of composite material made up by continuous fiber

Assumption:
1. Fiber are uniformly distributed through out the matrix
2. Perfect bonding between fiber and matrix
3. No void
4. Applied loads are either parallel or normal to the fiber direction.
5. Lamina is initially in a stress-free state.
6. Fiber and matrix behave as linearly elastic materials.



$$E_c = E_f V_f + E_m V_m$$

$$E_c = \frac{E_m E_f}{E_f V_f + E_m V_m}$$

Where,
E= Young's modulus
V= volume fraction
f = fiber
m= matrix
c= composite

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Research Interest:

- High Temperature Physical Chemistry
- Thin Films Technology
- Metals and Alloys.

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Research Interest:

- ❑Natural-fiber composites
- ❑Polymer based materials.

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