UNIT III COMPOSITES AND ADHESIVES

Composites consist of:

1) Combination of two or more materials – Composite = matrix + fiber (filler):

    Matrix:

    (i) material component that surrounds the fiber.
    (ii) Usually **a ductile, or tough, material w/ low density**
    (iii) **Strength usually = 1/10 (or less) than that of fiber**
    (iv) Examples include: thermoplastic or thermoset
        a. Thermoset most common (epoxy, pheneolic)
    (v) Serves to hold the fiber (filler) in a favorable orientation.

    Fiber aka reinforcing material aka Filler:

    (vi) **Materials that are strong with low densities**
    (vii) Examples include glass, carbon or particles.

2) Designed to display a combination of the best characteristics of each material i.e. fiberglass acquires strength from glass and flexibility from the polymer.
3) Matrix and filler bonded together (adhesive) or mechanically locked together!

Where are composites used??????

CFRP – carbon fiber reinforced composite.

GFRP – glass fiber reinforced composite

Advantages:

a) High strength to weight ratio (low density high tensile strength) or high specific strength ratio!
   i) 1020 HRS spec strength = 1 (E6 in)
   ii) Graphite/Epoxy, spec strength = 5 (E6 in)
b) High creep resistance
c) High tensile strength at elevated temperatures
d) High toughness
e) Generally perform better than steel or aluminum in applications where cyclic loads are encountered leading to potential fatigue failure (i.e. helicopter blades).
f) Impact loads or vibration – composites can be specially formulated with high toughness and high damping to reduce these load inputs.
g) Some composites can have much higher wear resistance than metals.
h) Corrosion resistance

i) Dimensional changes due to temp changes can be much less.

j) Anisotropic – bi-directional properties can be design advantage (i.e. helicopter blades)

Disadvantages (or limitations):

a) Material costs
b) Fabrication/ manufacturing difficulties
c) Repair can be difficult
d) Wider range of variability (statistical spread)
e) Operating temperature can be an issue for polymeric matrix (i.e. 500 F). Less an issue for metal matrix (2,700 F).
f) Properties non-isotropic makes design difficult!
    i) Example – video test in line w/ fibers 10X stronger vs fibers oriented at an angle.
g) Inspection and testing typically more complex.

Classification of Composite Materials by Matrix:

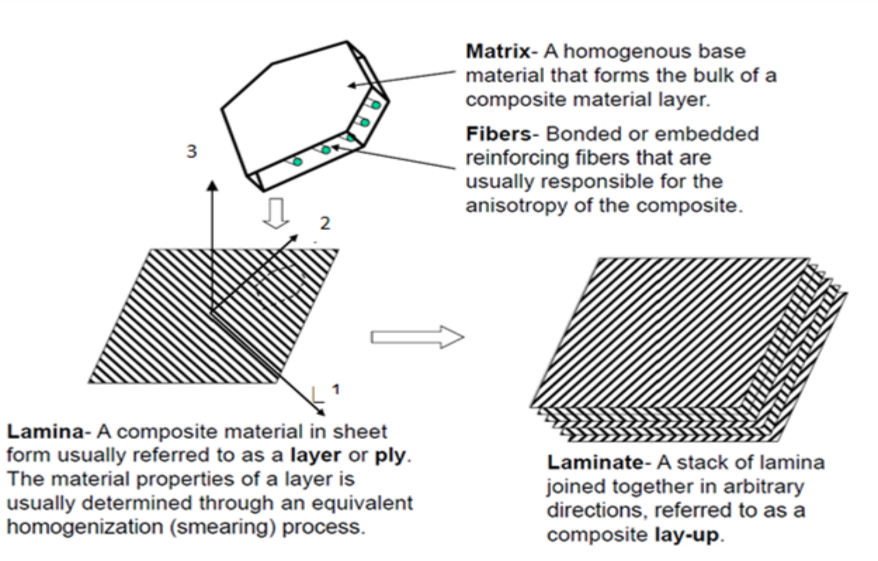
1. Metal matrix
2. Ceramic matrix
3. Polymer (Resin) matrix

Most common – also called fiber reinforced polymer

Classification of Composite Materials by Matrix:

1) Polymer matrix composites or Fiber Reinforced Polymer (FRP)
    a) Fibers generally glass, carbon or kevlar
    b) Matric can be:
        i) Thermoplastics: PE, Nylon, PS, PP, PC, PVC
        ii) Thermosets: Epoxy, polyester, phenolics
    c) Have high strength and stiffness to weight ratio
    d) Aerospace, sporting goods marine
    e) Examples: GFRP aka fiberglass (polyester or epoxy and glass), CFRP (polyester or epoxy and carbon), KFRP (polyester or epoxy and Keflar)

Layered Composites



Ranking of Most Common Fibers for FRP

Property	Glass	Carbon	Kevlar
Strength	Worst	In - between	Best
Stiffness	Worst	Best	In – between
Cost	Best	Worst	In – between
Weight	Worst	Best	In-between

Classification of Composite Materials by Matrix:

Metal matrix composites (MMC):

a) Metal matrix: Al, Ti, Mg, Fe, Cu, Ni

b) Example: Al-SiC (silicon carbide)

c) Example: Al-Al_2O_3 (aluminum oxide)

High strength, high stiffness, abrasion resistance, dimensional stability, high temperature and toughness.

Ceramic matrix composites (CMC):

a) Silicon carbide-silicon carbide (SiC-SiC)

b) Same material both matrix and filler BUT filler different form such as whickers, chopped fibers or strands to achieve preferred properties.

The strength of the composite depends primarily on the amount, arrangement and type of fiber (or particle) reinforcement in the resin.

Typically, the higher the reinforcement content, the greater the strength. In some cases, glass fibers are combined with other fibers, such as carbon or aramid (Kevlar29 and Kevlar49), to create a "hybrid" composite that combines the properties of more than one reinforcing material.

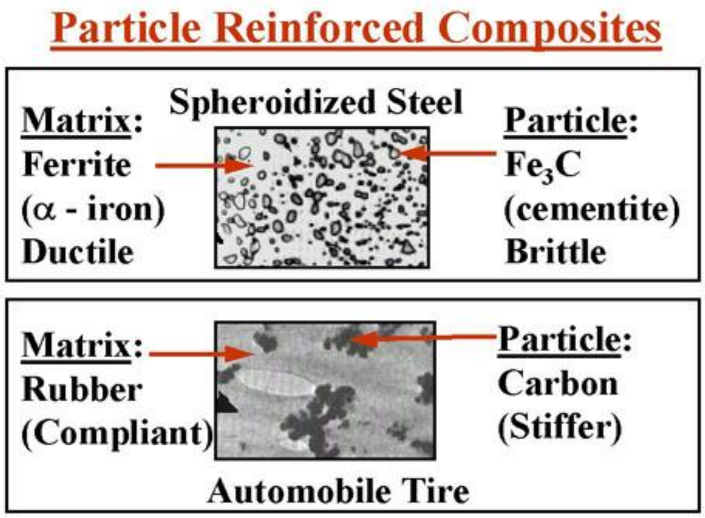
Classification of Composite by Filler Type:

- Particle-reinforced composites
- Fiber-reinforced composites
- Structural composites

Particle Reinforced Composites:

1) Particles used for reinforcing include:
   a) ceramics and glasses such as small mineral particles,
   b) metal particles such as aluminum,
   c) and amorphous materials, including polymers and carbon black.
2) Particles are used to increase the modulus of the matrix, to decrease the permeability of the matrix, or to decrease the ductility of the matrix.
3) Particle reinforced composites support higher tensile, compressive and shear stresses
4) Particles are also used to produce inexpensive composites.
5) Examples:
   a) automobile tire which has carbon black particles in a matrix of elastomeric polymer.
   b) spheroidized steel where cementite is transformed into a spherical shape which improves the machinability of the material.
   c) concrete where the aggregtes (sand and gravel) are the particles and cement is the matrix.

Figure Examples for particle-reinforced composites. (Spheroidized steel and automobile tire)



Fiber-reinforced Composites:

1) Reinforcing fibers can be made of metals, ceramics, glasses, or polymers that have been turned into graphite and known as carbon fibers. Fibers increase the modulus of the matrix material. The strong covalent bonds along the fiber's length gives them a very high modulus in this direction because to break or extend the fiber the bonds must also be broken or moved. Fibers are difficult to process into composites which makes fiber-reinforced composites relatively expensive. Fiber-reinforced composites are used in some of the most advanced, and therefore most expensive, sports equipment, such as a time-trial racing bicycle frame which consists of carbon fibers in a thermoset polymer matrix. Body parts of race cars and some automobiles are composites made of glass fibers (or fiberglass) in a thermoset matrix.
2) The arrangement or orientation of the fibers relative to one another, the fiber concentration, and the distribution all have a significant influence on the strength and other properties of fiber-reinforced composites. Applications involving totally multidirectional applied stresses normally use discontinuous fibers, which are randomly oriented in the matrix material. Consideration of orientation and fiber length for a particular composites depends on the level and nature of the applied stress as well as fabrication cost. Production rates for short-fiber composites (both aligned and randomly oriented) are rapid, and intricate shapes can be formed which are not possible with continuous fiber reinforcement.

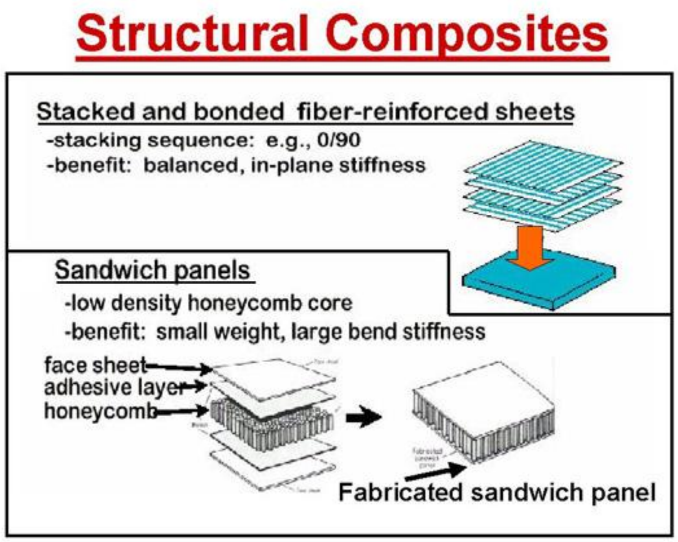
Structural Composites:

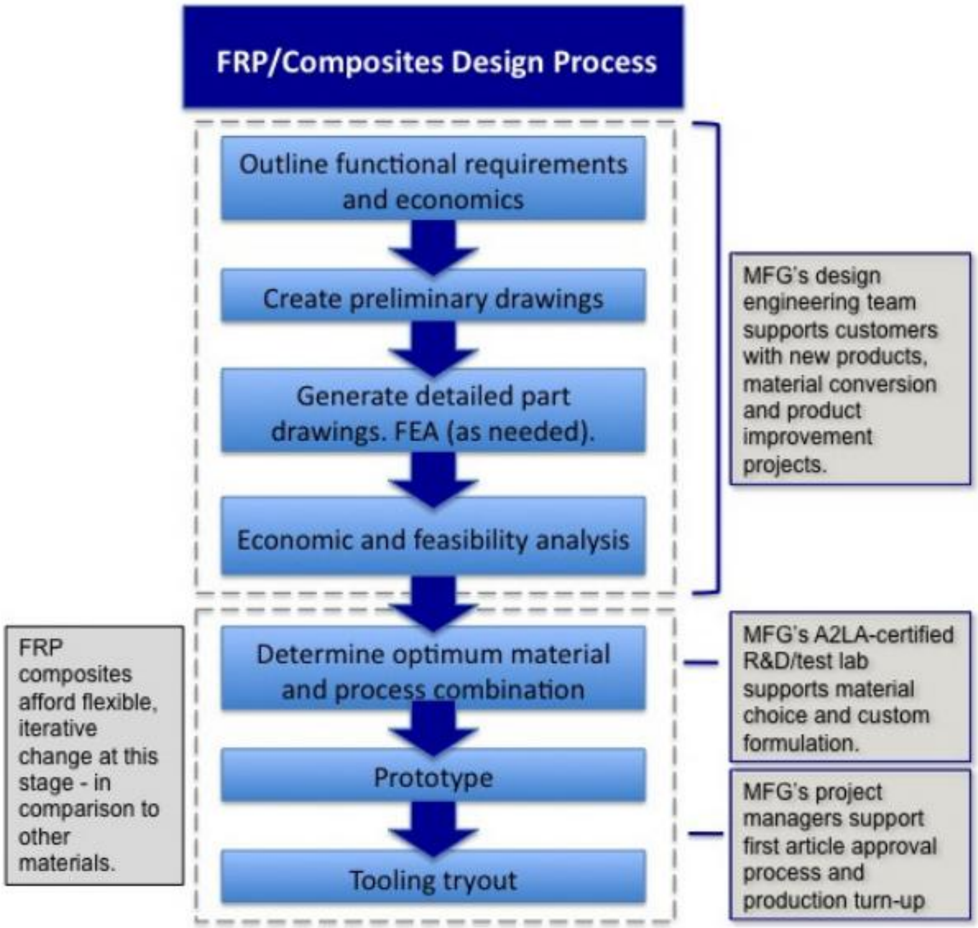
1) The properties of structural composites depend on:
   a) Constituents

b) Geometrical design

Common structural composite types are:

Sandwich Panels: Consist of two strong outer sheets which are called face sheets and may be made of aluminum alloys, fiber reinforced plastics, titanium alloys, steel. Face sheets carry most of the loading and stresses. Core may be a honeycomb structure which has less density than the face sheets and resists perpendicular stresses and provides shear rigidity. Sandwich panels can be used in variety of applications which include roofs, floors, walls of buildings and in aircraft, for wings, fuselage and tailplane skins.




FRP/Composites Design Process
Outline functional requirements and economics
Create preliminary drawings
Generate detailed part drawings. FEA (as needed).
Economic and feasibility analysis
Determine optimum material and process combination
Prototype
Tooling tryout
MFG's design engineering team supports customers with new products, material conversion and product improvement projects.
MFG's A2LA-certified R&D/test lab supports material choice and custom formulation.
MFG's project managers support first article approval process and production turn-up
FRP composites afford flexible, iterative change at this stage - in comparison to other materials.