Composites

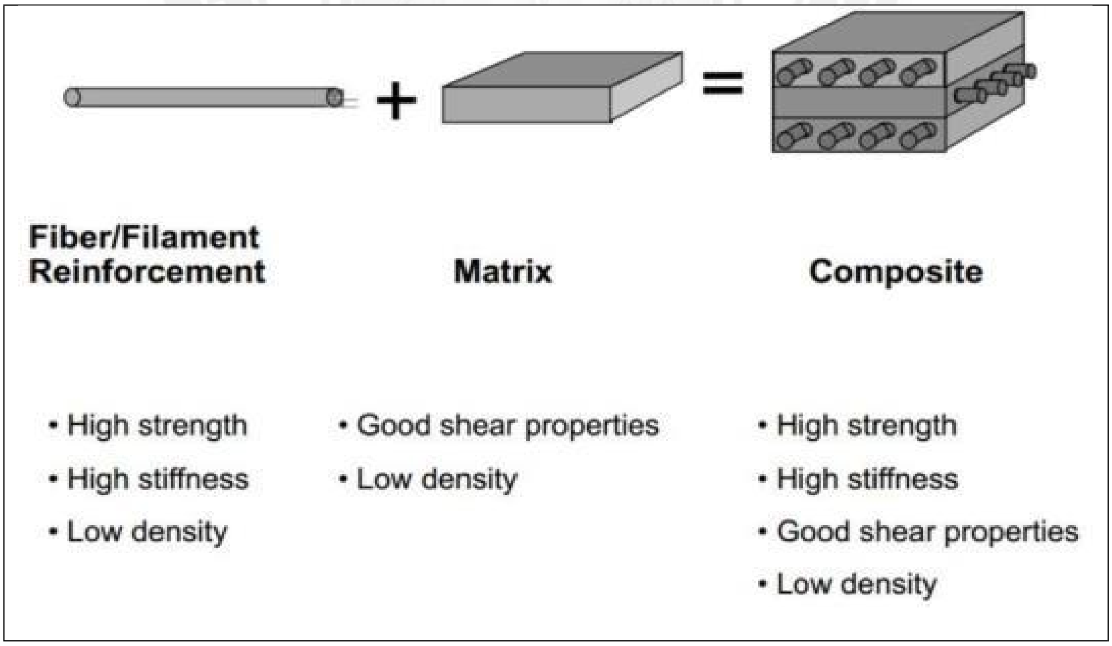
Definition

- ❖ Composites are combinations of two materials in which one of the materials, called the reinforcing phase, is in the form of fibers, sheets, or particles, and is embedded in the other materials called the matrix phase. The reinforcing material and the matrix material can be metal, ceramic, or polymer.
- ❖ Composites are artificially produced multiphase materials.

Composite Material

- ✓ A combination of two or more materials to form a new material system with enhanced material properties.

Reinforcement + Matrix = Composite



Advanced Composite Materials

✓ Definition: An advanced composite material comprises at least two chemically different materials (heterogeneity): reinforcement, and a matrix that binds the reinforcement and is separated from it by a sharp interface.

Phases of the composites

- Matrix Phase: Polymers, Metals, Ceramics, continuous phase, surrounds other phase (e.g.: metal, ceramic, or polymer)
- Reinforcement Phase: Fibers, Particles, or Flakes, dispersed phase, discontinuous phase (e.g.: metal, ceramic, or polymer) *f*

→ Interface between matrix and reinforcement

The Main Characteristics of Composite Materials

- Heterogeneity: Non-uniformity of the chemical/physical structure
- Anisotropy: Direction dependence of the physical properties
- Symmetry: Tensorial nature of material properties
- Hierarchy: Stacking of individual structural units

Role of matrix and reinforcement

- Holds the fibres together.
- Protects the fibres from environment.
- Distributes the loads evenly between fibres so that all fibres are subjected to the same amount of strain.
- The compatibility, density, tensile strength, chemical and thermal stability of the reinforcement with matrix material is important for material selection, fabrication as well as application.
- In reinforced Composites, the matrix is the major load bearing constituent. The role of the reinforcement is to strengthen and stiffen the composite through prevention of matrix deformation by mechanical restraint. It also provides stability to the composite material.

- The matrix must stand up to the service conditions, viz., temperature, humidity, exposure to ultra-violet environment, exposure to chemical atmosphere, abrasion by dust particles, etc.

Classification of Composites

- Composite materials are commonly classified at following two distinct levels:

The first level of classification

- This is usually made with respect to the matrix constituent. The major composite classes include:

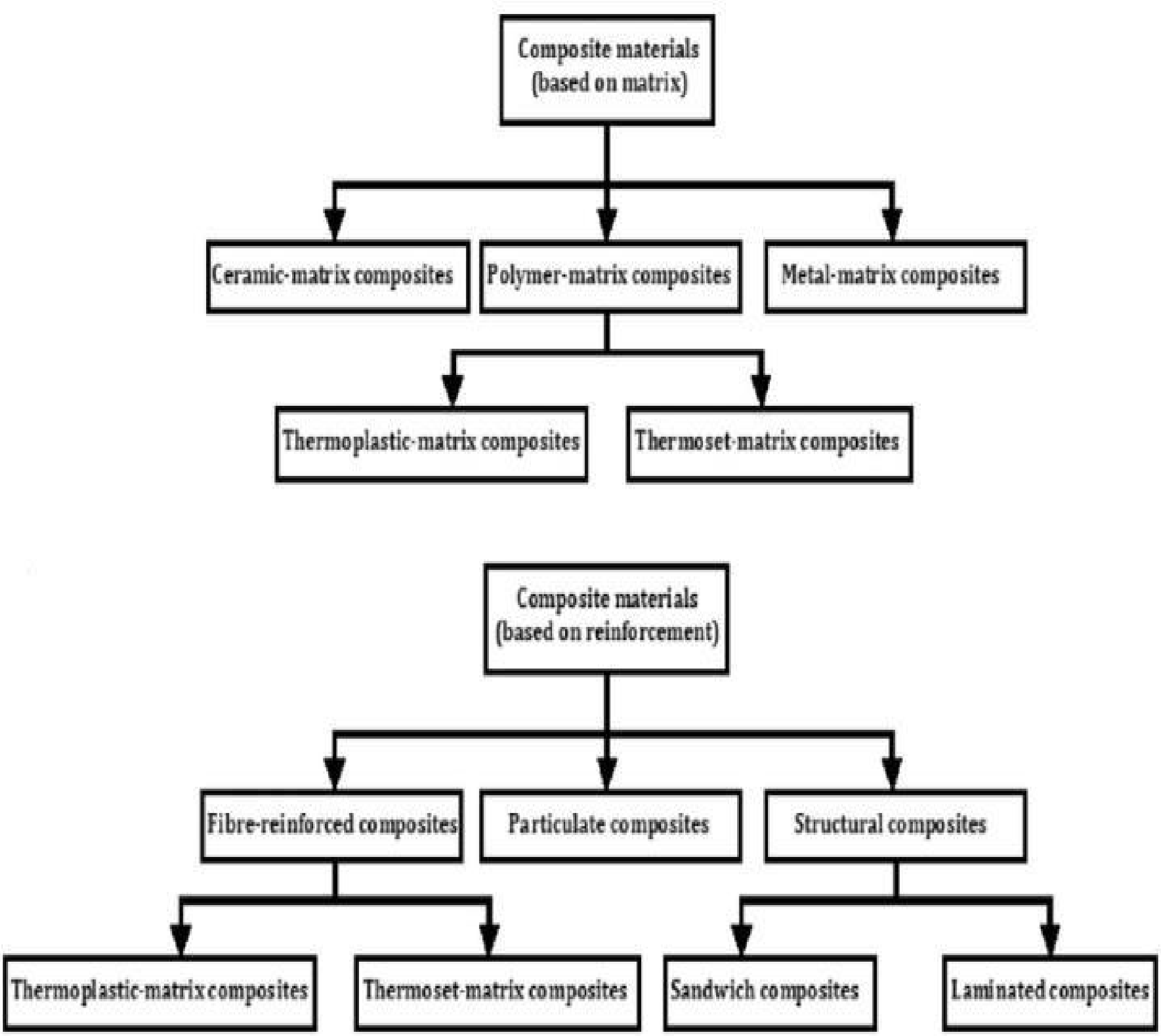
  (1) Organic Matrix Composites (OMCs),

  (i) Polymer Matrix Composites (PMCs)

  (ii) Carbon matrix composites (carbon-carbon composites)

  (2) Metal Matrix Composites (MMCs)

  (3) Ceramic Matrix Composites (CMCs)



Classifications of Composites

The second level of classification

- ❖ This refers to the reinforcement form

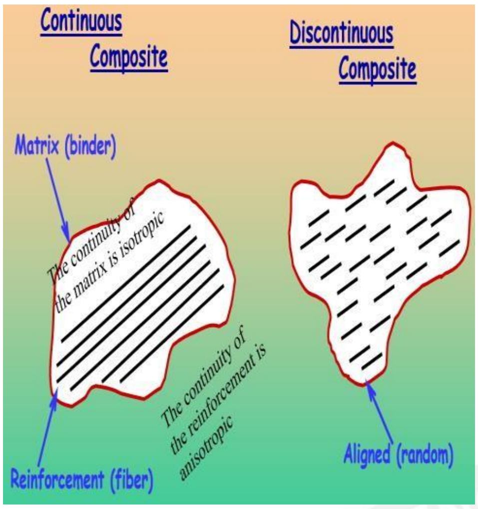
  (1) Fibre reinforced composites

  (i) Discontinuous fibres

  (ii) Continuous fibres

  (2) Laminar reinforced composites

  (3) Particulate reinforced composites



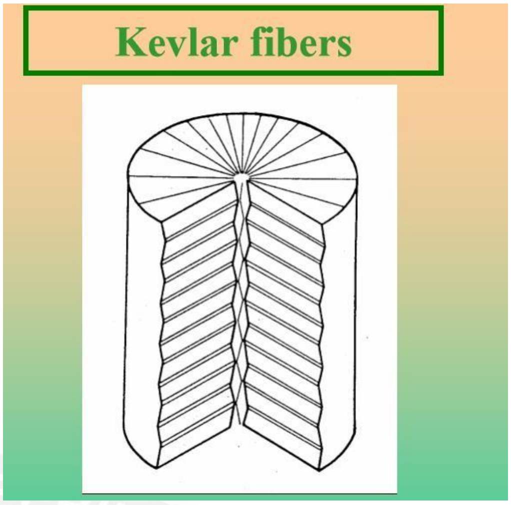


Figure.5.3.Continuous &discontinuous fiber Kevlar fibers

Fibre-Reinforced composites

- Fibre-reinforced composites are those in which the dispersed phase is in the form of a fiber. In fibre-reinforced composites, high-strength fibres are encased within a tough matrix. The greatest reinforcing effect is obtained when fibers are continuous and parallel to one another, and maximum strength is obtained when the composite is stressed in tension in a direction parallel to the line of fibers.
- When such a composite is stressed within the elastic range, the strain developed in both fibers and matrix will be the same.
- If fibers are discontinuous, their strengthening effect will be less than that of continuous fibers. Also short discontinuous fibers will be considerably less effective than long fibers. Most fibre-reinforced components provide improved strength, fatigue resistance, stiffness and strength-to-weight ratio.

Characteristics of fibre-Reinforced composites

- Low relative density and hence high specific strength and modulus of elasticity.
- Good resistance to corrosion
- Good fatigue resistance, particularly parallel to fibre direction
- Generally low coefficient of thermal expansion

Many factors influence the characteristics of fibre-reinforced composites

- The length, diameter, orientation, amount and properties of the fibers.
- The properties of the matrix
- The bonding between the fibers and matrix

Fibre and matrix materials

- Some of the commonly used fibre and matrix materials in the fibre-reinforced composites are listed below:

S.No	Fibre materials	Matrix materials
1.	Polymers(Kevlar,nylon, polyethylene)	Thermosetting resins (Polyesterresins,epoxide resins)
2.	Metals(Be,Boron,W)	Thermoplastics(PA, PAI,PBT,PET,PES,PPS,PEEK)
3.	Glass(E-glass, S-glass)	Metal matrices(Al,Ti,Mg,Crand Ni together with their alloys)
4.	Carbon(high strength, high modulus)	Composite matrices
5.	Ceramics(Al_2O_3, B_4 C, SiC, ZrO_2)	
6.	Whiskers(Al_2O_3,Cr,graphite,SiC,Si_3N_4)	

Examples

- Some of the important fibre-reinforced composites and their typical applications are given below:

S.No	Fibre-reinforced composite system	Typical applications
1.	Borsic aluminium	Fan blades in engines, other aircraft and aerospace applications
2.	Kevlar-epoxyand Kevlar-Polyester	Aircraft, aerospace applications(space shuttle), boat hulls, sporting goods(tennis rackets, golf club shafts, fishing rods), flak jackets
3.	Graphite-polymer	Aerospace and automotive applications, sporting goods
4.	Glass-polymer	Light weight automotive applications, wear and marine applications, corrosion-resistant applications, sporting goods equipment, aircraft and aerospace components

Fiber Reinforced Polymer (FRP) Composites

- ✓ "A matrix of polymeric material that is reinforced by fibers or other reinforcing material”

Laminar Composites

- ✓ They are composed of layers of materials held together by matrix. Sandwich structures fall under this category.

Particulate Composites

- ✓ They are composed of particles distributed or embedded in a matrix body. The particles may be flakes or in powder form.

Example

- ❖ Concrete -hard particles (gravel) + cement (ceramic/ceramic composite). Properties determined by particle size distribution, quantity and matrix formulation
- ❖ Electrical contacts (silver/tungsten for conductivity and wear resistance)
- ❖ Cast aluminium with SiC particles

Metal Matrix Composites (MMCs)

- ✓ A metal matrix composite (MMC) is a type of composite material with at least two constituent parts, one being a metal. The other material may be a different metal or another material, such as a ceramic or organic compound. When at least three materials are present, it is called a hybrid composite.

Advantages of composite materials

- Composite materials exhibit superior mechanical properties such as high strength, toughness, elastic modulus, fairly good fatigue and impact properties.
- As fibre composites are light weight materials, the specific strength and specific modulus are much higher than the conventional materials.
- In aerospace applications, the power to weight ratio is about 16 with composites compared to 5 with conventional materials.
- They exhibit good corrosion resistance.
- Assembly of components made of composites is much easy and quick.
- They are not much sensitive to thermal shocks and temperature changes.
- High Strength with Low Weight: Composites exhibit a higher strength to weight ratio than steel or aluminum and can be engineered to provide a wide range of tensile, flexural and impact strength properties.

Limitations of composites

- ❖ High cost of raw materials and fabrication.
- ❖ Composites are more brittle than wrought metals and thus are more easily damaged.

- Matrix is weak, therefore, low toughness.
- Reuse and disposal may be difficult.
- Difficult to attach

Applications of Composites

- **Commercial aircraft:**

  Used for air-conditioning duct, radar dome, landing gear door, seats, floorings, window reveals, ceiling panels, propeller blades, nose, wing body, elevators, ailerons, air brake, etc.
- **Military aircraft:**

  Used for speed brake, rubber trunnion, forward fuse lag, elevators, ailerons, landing gear doors, horizontal stabilizers, etc.
- **Missiles:**

  Used for remote piloted vehicles, filament wound rocket motors, wings, rotor cases etc.
- **Space hardwares:**

  Used for antennas, struts, support trusses, trusses for telescopes, storage tanks for gases and fluids at cryogenic temperatures etc.
- **Automobile and trucks:**

  Used for drive shafts, bumpers, door and window frames, starter motor commutators, body panels, radiator and other hoses, timing and V belts, drive chains etc.
- **Electrical and electronics:**

  Used for microphone housing, miniature-electronic card holder, ribs to protect printed circuit boards, parabolic antenna etc.; electrical equipments-switch casings, cable and distribution cabinets, junction boxes etc.
- **Marine applications:**

  Used for small boat hulls, sonar domes, masts, tanks, decks, submarine masts, spinnaker pole on the racing yatch, plates in nuclear submarine lead acid batteries etc.