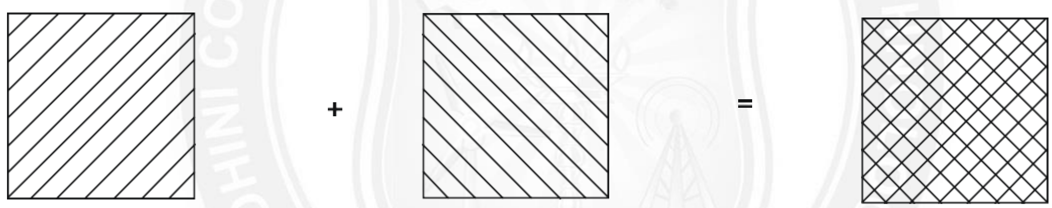
4.3 COMPOSITES

DEFINITION

Composite materials, are a combination of two or more materials that are different in chemical composition. The materials are blended to create a material with superior structure and better properties than the constituent materials.

Composite materials can be a combination of various materials, such as plastics, metals, fibers or ceramics.

However, the properties of a composite material depend on the properties, structure, and proportion of the constituent materials. Figure 4.3.1 shows how two different materials combine to form a composite material.



Composites usually consist of two parts, the matrix and the reinforcements. The matrix holds the reinforcements, transfers the load to the reinforcements, and protects them from mechanical and environmental damage. The reinforcements carry most of the load and provide stiffness.

Some composite materials exhibit better properties than the constituent materials, such as metals or plastics. Therefore, composite materials are preferred over other materials in applications such as aircraft manufacturing, space vehicles, electronics and sporting goods.

Matrix materials

In composites, the matrix phase serves important functions.

First it binds the reinforcement (fibers) together. It acts as a medium and transmits and distributes the external loads to the fibers.

The second function of the matrix is to protect the individual fibers from surface damage due to mechanical abrasion or chemical reaction with the environment.

In order to minimize fiber pull out, it is essential to have high adhesive forces between the fiber and matrix. The matrix material should be ductile.

The strength of the resulting composite depends to a large extent on the magnitude of bonding strength between fiber and matrix. The bonding ensures proper stress transmittance from the weak matrix to the strong fibers.

Reinforced materials

In composite materials, the reinforcement is responsible for higher strengths.

Two main forms of reinforcements used are:

(a) Fibers

(b) Particles

(a) **Fibers:** The materials used for reinforcing fibers have high tensile strengths. Based on the diameter and character, fibers are classified as follows.

(i) **Whiskers:** These are very thin crystals with extremely large length to diameter ratios. Because of their small size they have perfect crystalline structure and are free from flaws.

Due to this they have exceptionally high strengths and perhaps they are the strongest of all known materials. Some of the common whisker materials include graphite, silicon carbide, silicon nitride and aluminium oxide.

(ii) **Fibers:** The fibers are either polycrystalline or amorphous materials having small diameters. Fibrous materials are generally either polymers or ceramics.Some common fibers used are polymer aramids, glass, carbon, boron, aluminium oxide, silicon carbide etc.

(iii) **Wires:** Wire have relatively large diameters compared to fibers. Typical materials include steel, molybdenum and tungsten.The arrangement or orientation of the fiber, fiber concentration and distribution, all have a significant

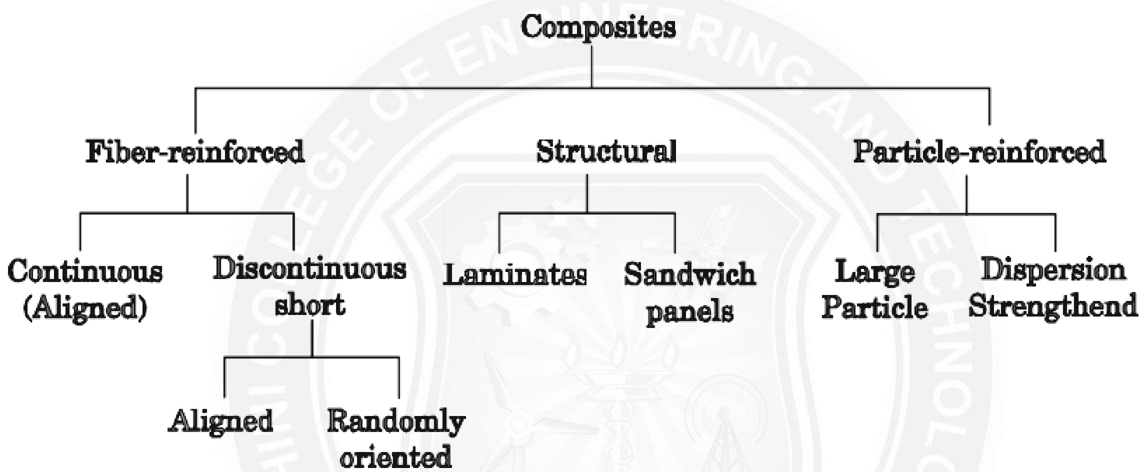
CLASSIFICATION OF COMPOSITES

Based on the reinforcement techniques, composites are classified as:

(a) **Fiber-reinforced**

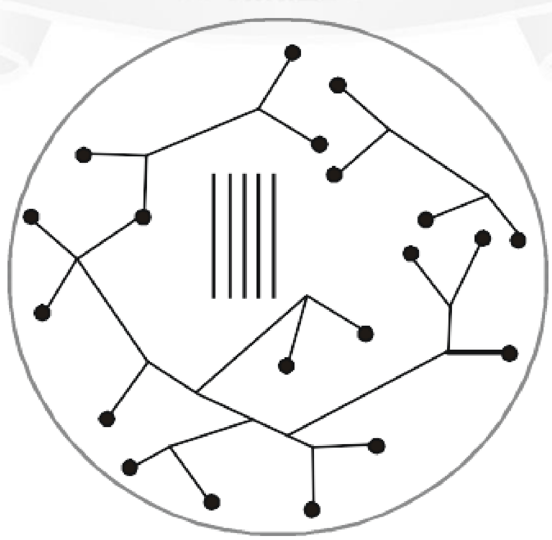
(b) **Structural**

(c) **Particle-reinforced**



Fiber - Reinforced

Fiber-reinforced composites consist of thin fibers of a material, which are suspended in a matrix of another material. Matrix is the medium or the substance in which the fibers are suspended.

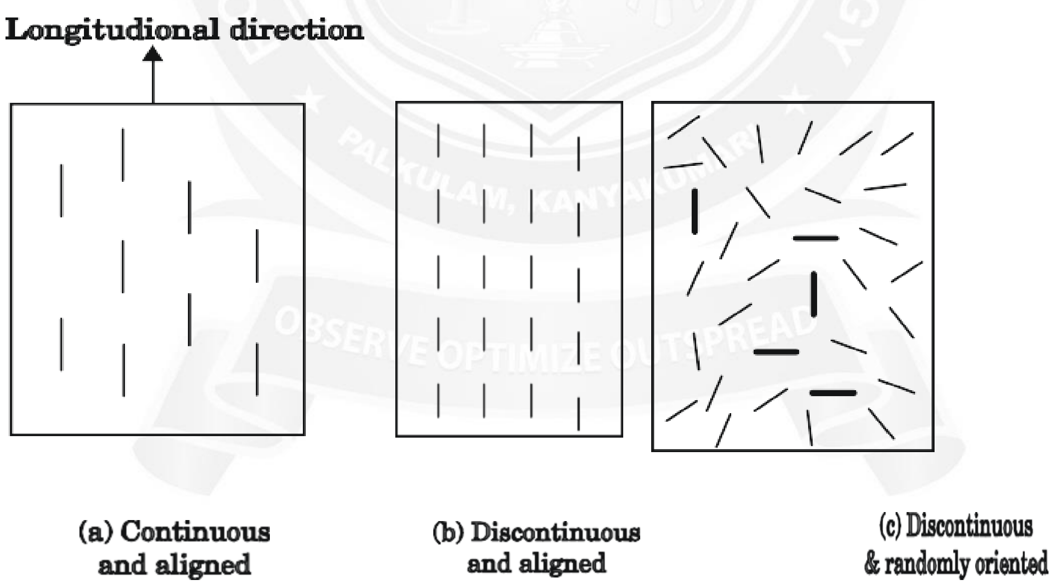


Matrix distributes the stress across the fibers. The thin continuous or discontinuous fibers provide strength to the composite. Matrix also provides toughness to the fiber- reinforced structure.

Example:

- One of the most common natural fiber-reinforced composites is bamboo, where cellulose fibers are suspended in a matrix of lignin.
- One of the manmade fiber-reinforced composites can be been in a car tyre, where nylon or steel wires are suspended in rubber matrix.
- Concrete is another manmade composite, where iron rods are used as reinforcing material with sand and gravel in the cement matrix.

Some commonly used reinforcing fibers are Kevlar, graphite, and glass.



(b) **Particles:** The particles having size of up to 1m or more in the concentrations of 20 to 40% have been used in composites.

Several metal particles such as tungsten, chromium, molybdenum etc, can be suspended in ductile matrix.

Non metallic particles such as ceramics can be suspended in metal matrix. The several metal oxides and carbides in the form of particles are used to produce metal matrix composites (MMC's).

Types of composites

Based on the matrix material

- ***Polymer matrix composites:*** In this the matrix material is a polymer, reinforced by ceramic. for example carbon or glass fiber reinforced with plastics.

- ***Metal matrix composites:*** In this composite, the matrix is a pure metal or an alloy and the reinforcement is a ceramic phase. Typical examples of metal matrix composites are Al - Al_2O_3 and Al-SiC.

- ***Ceramic matrix composites****:* The matrix and reinforcements are generally ceramics.

In these composites the stiffness and hardness of ceramics is combined with toughness of polymers or metals. Typical examples of ceramic matrix composites are glass-and carbon-fiber-reinforced plastics.

Fibre reinforced plastics(FRP)

It is a composite material. We know that the composite materials have been developed to get improved or desired properties in them. Nowadays fiber reinforced plastics (FRP) plays an important role in the machine parts where we require high strength, high modulus, heat resistance and light weight.

The fibrous glass is used in reinforced plastics in the form of ravings, chopped strands, milled fibers, yarns, mats and woven fabrics. Most commonly used reinforcements are

(i) Random chopped strand mat, bonded together with a resinous binder (polyster).

(ii) Mat from continuos strands, deposited in a swirl pattern and loosely bonded together with a resinous binder.

(iii) Filament type thin mats.

(iv)Performs

(v) Woven fibrous glass clothes.

(vi)Parallel stranded glass fibers

(vii) Short stranded

The glass fibers having a vinyl silence-epoxy surface treatment on the fibers are used. This treatment gives best dry and wet strength. E type glass is one of the important glass fiber materials which use boric acid rather than soda ash as one of the component of the melt. Mostly polyester resin is used as plastic. Epoxy and phenolic resins are also used.

The fibers are made from synthetic textile fibers treated in such a way that the side groups are entirely removed. The carbon fiber reinforced plastics are used in aeroengines, high pressure rotor and stator blades since they can withstand higher thrusts. Silica and boron fiber reinforced plastics have high strength and low density. But these are all costlier than glass or carbon fiber reinforced plastics.

Advantages

1. It has high strength to weight ratio
2. It has low cost tooling.
3. Large shapes are possible in one piece. Since it can be fashioned more easily than a metal it is used in making complicated machine parts.
4. Excellent environment exposure resistance can be obtainable.
5. It has excellent electrical properties.
6. It has higher heat resistance.

Disadvantages

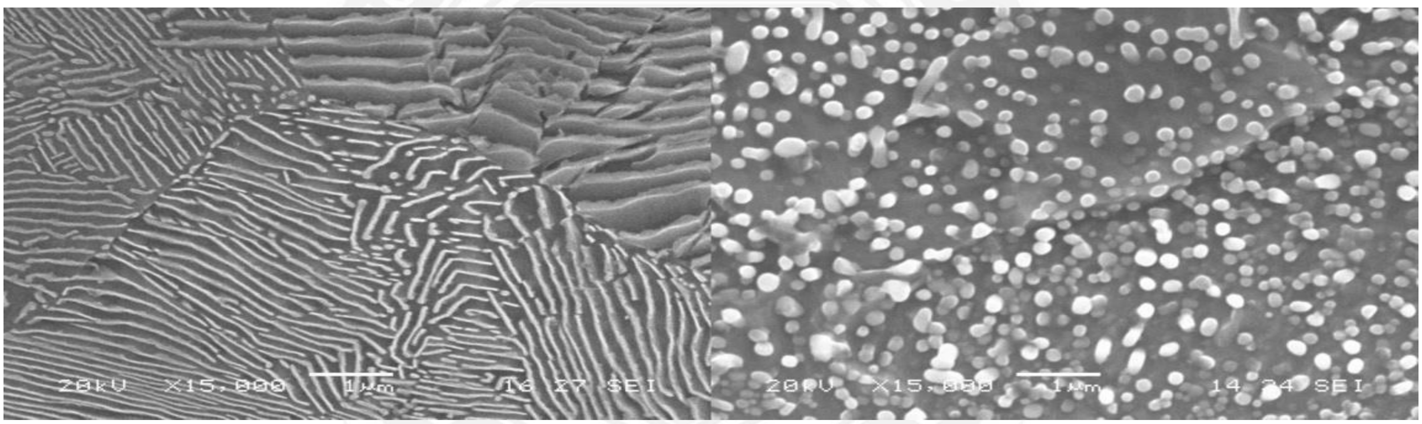
1. The material cost is so high.

2. The strengths perpendicular to fiber orientations are low.
3. It has low rate of heat transfer and dissipation.
4. It has lower flexural modulus than steel and requires higher thickness .

Fiber reinforced metal(FRM)

Fiber reinforced metals (FRM) are composites, which are made up of inorganic fibers fabricate with metal.

FRM are composed of fibers (reinforcement phase) and metals (matrix phase). The following diagram exhibits the FRMs (silicon fiber reinforced in metals).



Fiber reinforced metal

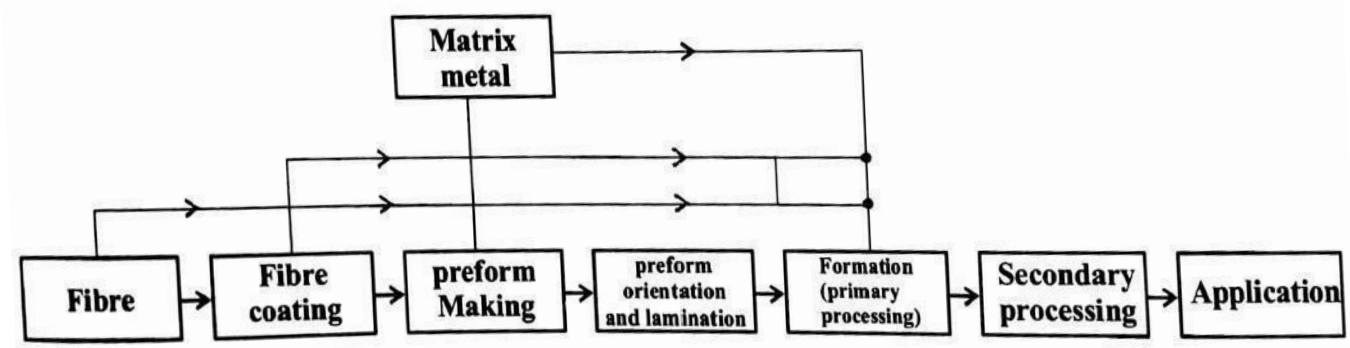
Fabrication of FRM

The fabrication of FRM consists of joining the interfaces of both phases. Before doing the fabrication of FRM, the reinforcement fibers and the matrix materials should be choosen carefully with light weight and high strength materials.

The reinforcement fibers and the corresponding matrix metals used for fabricating FRM are given below.

S. No	Reinforcement Fibers	Matrix metals	Composite System
1.	Boron	Al and Mg	Boron System

2.	Carborundum	Al and Ti	Corborundum System
3.	Carbon	Al, Mg and Cu	Carbon System
4.	Alumina	Al and Mg	Alumina System



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1. Depending upon requirements, fibers are given pre-treatment such as fibre coating to improve wetting and joining ability with matrix metals and to prevent failure caused by reaction between different surfaces.
2. Then, performs are made, which are cut to the required dimensions.
3. These performs are oriented and laminated according to the design specifications of the components.
4. The next process is called forming (primary processing) in which composition and shaping is carried out.
5. At this stage the matrix metal and the reinforcement fibers are primarily processed together to form the FRM composite.
6. After forming the FRM, the secondary processing such as cutting, trimming and joining is done.

   Thus the fabrication is complete and shall be used for further applications.

Properties of FRM

i) FRM is light weight

ii) FRM has a high stiffness

iii) FRM possess high strength at high temperatures [i.e. 200 to 400 ˚C].

iv) FRM are high in inter-lamina strength and stress transmissibility between filaments and highly resistant to polyaxial and complex stress.

v) FRM are resistant to impact and superior in extreme low temperature characteristics.

vi) FRM are infiltrated by water and are not corroded by rain.They do not equire any measures against lightning strike or static, nor any coating for electromagnetic shielding

Applications of FRM

i) FRM are used in constructing space machines and satellite body structures. The material system used for this are B/Al, B/Mg, C/Al, C/Mg.

ii) FRM are to make pylons, frames, beams, fans, compressor blades, fairings, wing boxes, access- doors in air crafts. The material systems used here are B/ Al, SiC/ Al.

iii) FRM are used to make truss structures in helicopters. The promising material systems used are B/ Al, SiC/ Al, Al2O3/ Al.

iv) FRM are used to make engine electric components such as motor brushes, cables, etc., C/Cu is the material systems used for these products.

v) FRM are used to make sports goods such as tennis rackets, Golf clubs, etc., the materials systems used for these are B/ Al, SiC/ Al, C/Al, Al2O3/ Al.