IMPORTANT PROPERTIES:

1.ceramic`s are in-organic, non-metallic materials that are pass and /or used at high temperatures

2. They have been subjected to heat treatment

3. They are generally hard & brittle materials that with stand compression very well

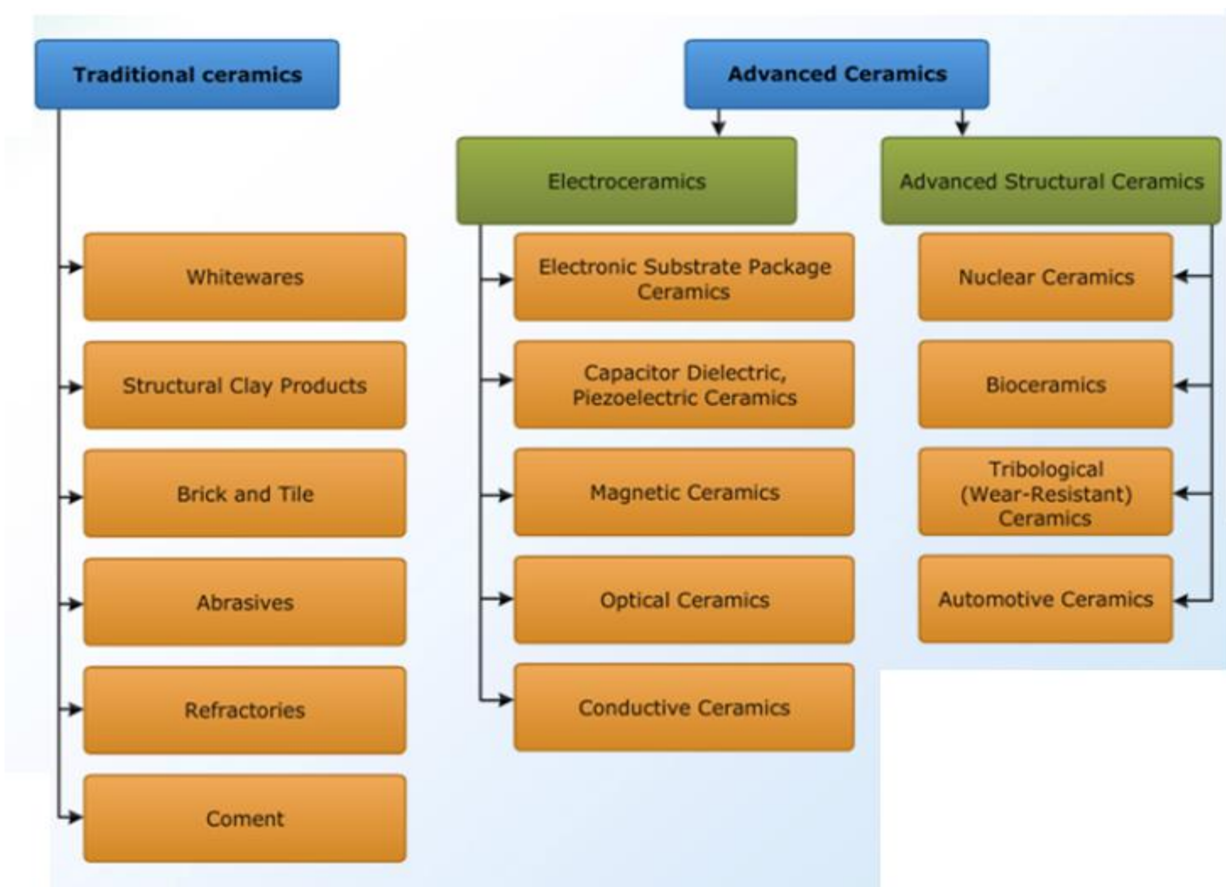
4. They are abrasive resistance, heat resistance &can curtain large compressive loads even at high temperature

5.many ceramic`s are chemically inert even at high temperatures as shown by good oxidation and reduction resistance at these temperature

6. The nature of chemical bond in ceramics generally ionic in character and the coins play on important role in the determination of the properties of the material

EX: anions, carbides, borides, nitrides, oxides.

TYPES OF CERAMIC`S: **1.**Classification of ceramics based on function



EXAMPLES OF CERAMIC MATERIALS:

1. All types of glass product including fibers etc..
2. Cements, line, plaster
3. Abrasives & some types of cutting of tools
4. Bricks, tiles, drain, pipes etc..
5. Refractories for high temperature use
6. Electrical insulators, Ferro magnetic, semi conductors

STRUCTURAL CLASSFICATION:

1. **CRYSTALLINE CERAMICS:**

   These are single phase like MGO to multi phase from MGO to AL2O3 binary system.

2. **NON-CRYSTALLINE CERAMICS**: natural & synthetic in-organic glasses.
3. **GLASS-BONDED CERAMICS**: fire clay products-crystalline phase are held in glass mat
4. **CEMENTS:** crystalline (or) non-crystalline phases.

ADVANTAGES OF CERAMIC MATERIALS:

1. The ceramics are hard, strong & dense.
2. They have high resistance to the action of chemically and to the weathering
3. Passes a high compression strength compressed with tension
4. They offer excellent di-electric properties
5. They are good thermal insulators
6. Good sanitation
7. Better economy

APPLICATIONS:

1.**WHITE WARES:** tools, sanitary wares, high frequency applications, chemical industries etc

2.**NEWER CERAMICS:** borides, carbides, nitrides, single oxides, mixed oxides, silicates, insulators, semi conductors, fuel elements, fuel containers, control rods etc..

3. ADVANCED CERAMICS: these are in I.C engines, turbines, cutting tools, energy conversation, strong & generation

PROPERTIES OF CERAMIC MATERIALS:

MECHANICAL PROPERTIES:

1. Compressive strength is high
2. It is brittle
3. These passes ionic & covalent bond
4. More force required
5. Rigidity high at temperature

ELECTRICAL PROPERTIES:

Di-electric constant:

It is the ratio of capacitance of a di-electric compared to the capacitance of air under the same conditions

Di-electric strength:

It is the ability of a material to with stand electrical break down volume & surfaces resistivity

Thermal properties:

1. Thermal conductivity
2. Thermal capacity
3. Thermal-shock-resistance

STRUCTURE OF CRYSTALLINE CERAMICS:

Most ceramic phases, like metals, have crystalline structure. Ceramic crystals are formed by either a pure ionic bond, a pure covalent (or) by bonds that passes the ionic as well as covalent characteristics.

Ionic bonds give ceramic materials of relatively high stability and high melting point

Covalent crystal:

1. Passes high hardness

2. High melting point & low electrical conductivity at room temperature

CRYSTAL STRUCTURES IN CRYSTAL CERAMICS:

1. Rock salt structure
2. zinc blend structure
3. worzite structure
4. spinel structure
5. fluorite structure
6. ilemenite structure
7. Cesium chloride structure

ADVANCED CERAMICS:

1. **Glass ceramics**:
   The compositions in which nucleation and crystallization have been commercially produced are MgO; Al_2O_3- SiO_2; LiO_2-AL_2O_3-SIO_2; LiO-MgO-SiO

Characteristics:

1. Very low co-efficient of thermal expansion

2. High mechanical strength and thermal conductivity

APPLICATOINS: over ware, table ware & as insulators

2. Die- electric ceramics:

Non linear electric ceramics are suitable in the miniaturation of electric part which have had to the development of increasingly sophisticated electrical circuits and also used in capacitors

2. **Electronic ceramics:**
   There are two types of electronic ceramics that are ferrite, Ferro-electric ceramics
   Ferrite are mixed metal-oxide ceramics
   - Ferro-electric ceramics are can convert electrical signal into mechanical energy

CERMETS:

- Cermets are ceramic & metal compositions
- It contains Al_2O_3 & Cr varying proportions.
- The most common cermets is the cemented carbide which is composed of extremely hard particles of a refractory carbide such as tungsten carbide (or) titanium
- These components are utilized extensively as cutting for hardened steels
- These are manufactured from the powders of ceramics metals by power metallurgy

APPLICATIONS:

1. These are used in jet engines, brake shoe, linings & oxidation resistant parts

2. Used as spinning tools for hot forging dies and other similar ten high temperatures applications

3. These also suitable for cutting of metals at high spends with medium to light chip loads

GLASSES:

1. Glass is a transparent silica product which may be amorphous (or) crystalline. Depending upon the heat treatment

2. Glass is in-organic product of faction in one (or) more oxides of silicon, boron, calcium, mg, Na etc … cooled to rigid material without crystallization

3. Glasses mostly consist of in-organic oxides such as SiO2 & B2O 3 are known as glass formers

many other oxides such as Al2O3, CaO, Na2o MgO etc…are added to glass forming oxides to obtain derived combination of properties such as refractories index, electrical conductivity etc…

STRUCTURE OF GLASS:

Unlike most other ceramic material glass is non-crystalline to manufacture it is a mixture of silica and other oxides is melted and then cooled to a rigid condition.

Glass does not change from liquid to solid at a fixed temperature but remains in the crystalline state and it is considered as a super cooled liquid

Fig: Amorphous non-crystalline structure of glass

GLASS PRODUCTION & PROCESSING STEPS:

1. Melting & refining ~ melting point = 1500 c
2. Forming & shaping
3. Heat treatment
4. Finishing

PROPERTIES OF GLASS:-

1**. Viscosity**: - which determines the suitability of glass for drawing into tubes, rods, for blowing & rolling

2. Chemical stability:-

Which determines the suitability of glass for making chemical wears & optical glasses

3.Optical properties:-this determine the stability of glass for use in optical system

4. **Mechanical properties**:-tensile strength & wear resistance.

5. **Electrical properties: -** good conductivity di-electric and determine the stability of glass for manufacturing the incandescent lamps, radio, valves, x-ray tubes etc

APPLICATIONS OF GLASS:-

1 in doors, windows, furnitures etc..

2. Laboratory equipment & chemical glass wear

3. X-ray tubes, glass tubes, fiber glass insulation, optical glasses

TYPES OF GLASSES:-

1. Soda lime (or) crown glass
2.flint glass
3.pyrex (or) heat resistant glass.

1) SODA LIME (OR) CROWN GLASS:-

1. It is the cheapest quality of glass

2. available in clean & clear state

3. Easily fusible at comparatively low temperatures.

COMPOSITION BY WEIGHT:-

Sand	–	75 parts
lime	-	12.5 parts
Soda	–	12.5 parts
Alumina	-	1 part
Waste glass 50	–	100 parts

Applications: - window glass, plate glass, bottles, glass etc…

2. FLINT GLASS:-

- ❖ it provide better lastre than sodium glass
- ❖ in this load provides brilliance & high polish

COMPOSITION BY WEIGHT: -

sand 100 parts

red lead 70 parts

potash 32 parts

waste glass 10 parts

Applications:- table wears, optical glasses, electrical resistance materials

3. PYREX (OR) HEAT RESISTANT GLASS:-

Which are used extensively for cooking utensils and laboratory wares, are borosilicate glasses.

COMPOSITION BY WEIGHT: -

Silica – 80 parts
borox oxide -14 parts
sodium oxide - 4 parts
alumina 2 parts with trasses of potassium oxide, calcium oxide, mg oxide..

HIGH SILICA GLASS: -

- These are containing 96% silica.
- These are used where high temperature resistance is required
- These are used regularly at temperatures up to about 900 c
- High silica glasses are have a very low thermal expansion co-efficient which accounts for this high resistance to thermal shock.

SPECIAL TYPES OF GLASS:-

Annealing glass, sheet glass, plate glass, fluted glass, ground glass, wired glass, safety glass, bullet-proof glass, insulating glass, foam glass, glass blocks, soluble glass, ultra violet glass, structural glass, glass fiber (or) glass war.

ABRASIVES:-

1.An abrasive is commonly made of ceramic material

2. An abrasive is hard, mechanically resistance i.e material used for grinding (or) cutting

3. An abrasive an wear away softer material

4. An abrasive may be natural (diamond) (or) synthetic

5. Synthatic abrasives are prefer because greater uniform of hardness & structure can be obtained and other desired properties can be introduced.

CLASSFICATION OF ABRASIVES:-

1. Hard Abrasives 2. Siliceous Abrasives

3. Soft Abrasives 4. Artificial Abrasives

1**. HARD ABRASIVES:-**

- These are diamond, corundum, emery and garnet
- (i) Diamond is a crystalline form of carbon found in nature diamond is the hardest material known and it out lasts other abrasive by factors of 10-100 more.

Uses: wire drawing dies, drills for drilling hard locks, dressing for grounding wheels, polishing (or) carbide metals glasses, ceramics etc

EMERY:-

1. It is a natural abrasive
2. Emery papers are used polishing metal

SILICEOUS ABRASIVES:-

These abrasives are quartz, flint, chart, quartzite, sand stone and plumice which are all compassed chiefly of silica.

Sand Stone:-

1. It is a natural abrasive
2. .it is used for sharpening wood working tools

Quartz:

1. It is a natural abrasive
2. It is used for sand paper for wood & fine grinding

ARTIFICIAL ABRASIVE: -

SiC:-

1. It is a synthetic, artificial (or) manufactured abrasive

2. To manufacture sic sand. Cock & sea dust are mixed at high temperature electrical arc (4500c) is passed through a mixture for a long time .the center of the mixture is converted into sic which is then crushed

$$SiO_2+2c\text{-----}SiC+CO_2$$

Applications: -

1. Sic better known by one of its trade name carborcndum
2. For making grinding wheels
3. for refraction material
4. .as heating, element in the electrically heated industrial furnaces
5. as pipe
6. 6.it is used as a pumps for pumping sand

Al_2O_3 (ALUMINIUM OXIDE):-

1. It is obtained by heating AL salts

2. A wide variation of properties is possible depending upon the treatment

3. It has a color, lighter then sic

4.it is not quite so hard as sic , but is tough and more resistance to impact

USES: -

1.for polishing cast iron, non-ferrous metals and high nature finishing of stainless steel.

2. Floor sanding machine

NANO TECHNOLOGY:-

- ❖ nano technology is the technology that controlles matter at a smaller scale can bring miniraiturisation of things

Which is a luxury for the present generation but nesting for the future generation?

- ❖ It is the only technology which is found to be multi disciplinary that the scientific communities of various disciplinary throughout the world are involved in developing a new kind of material era..

Various studies of a nano particle, revels, that at nano scale, the properties of traditional materials change and the behavior of surface starts to dominate the behavior of bulk material

- ❖ Nano materials are crystalline materials having grain size on the order of many atoms
- ❖ nano materials normally have grain size very from microns to millimeter
- ❖ A micron is a millionth of meter (10^6). A nano meter is very smaller then even microns with is a billionth of meter (10-9)
- ❖ nano materials can be in-organic, organic as well as bio-organic materials
- ❖ Anano-crystalline materials have grain of the order of 1-100mm

MAJOR FIELDS OF NANO TECHNOLOGY:-

- ❖ One of the important fields of development in the biotechnological field.
- ❖ In this field the manipulation of genes tissue engineering, drug system etc…of nano sale levels
- ❖ This technology is used in computers, cell phones, bio-medical robots, batteries, sensors. Solar cells etc.Will produce fruit feel results & in the future.

AREAS OF COMMERTIAL APPLICATION OF NANO TECHNOLOGY IN FEATURES: -

even through the real fruits of nano technology will reach the people after 10-18 years period of time these include tissue engineering, genetic engineering, cancer research, medical imaging system, carbon nano tubes, sensors, lubricants, films, paints, explosives, textiles etc..

`APPLICATIONS OF NANO MATERIALS:-

1.**Tougher & harder cutting tools** :-

Nano materials cutting tools made of nano crystalline, tic, tantalum, carbide are extremely tough with very high wear-resistance. Such cutting tools can operate at higher temperatures with higher speed reducing the production time.

Also miniaturized cutting tools such as micro drill and cutters with enhanced edge, endurance and wear resistance. can Successfully careful in micro electronic system

❖ **Mechanical ceramics**:- sic, silicon nitride, have been applied in automatic applications such as high strength springs ,ball bearings ,due to their excellent physical chemical & mechanical properties

COMPOSITE MATERIALS:-

Composite materials are produced by combining two dis-similar materials into a new material that may be better suited for a particular application than either of the original material alone.

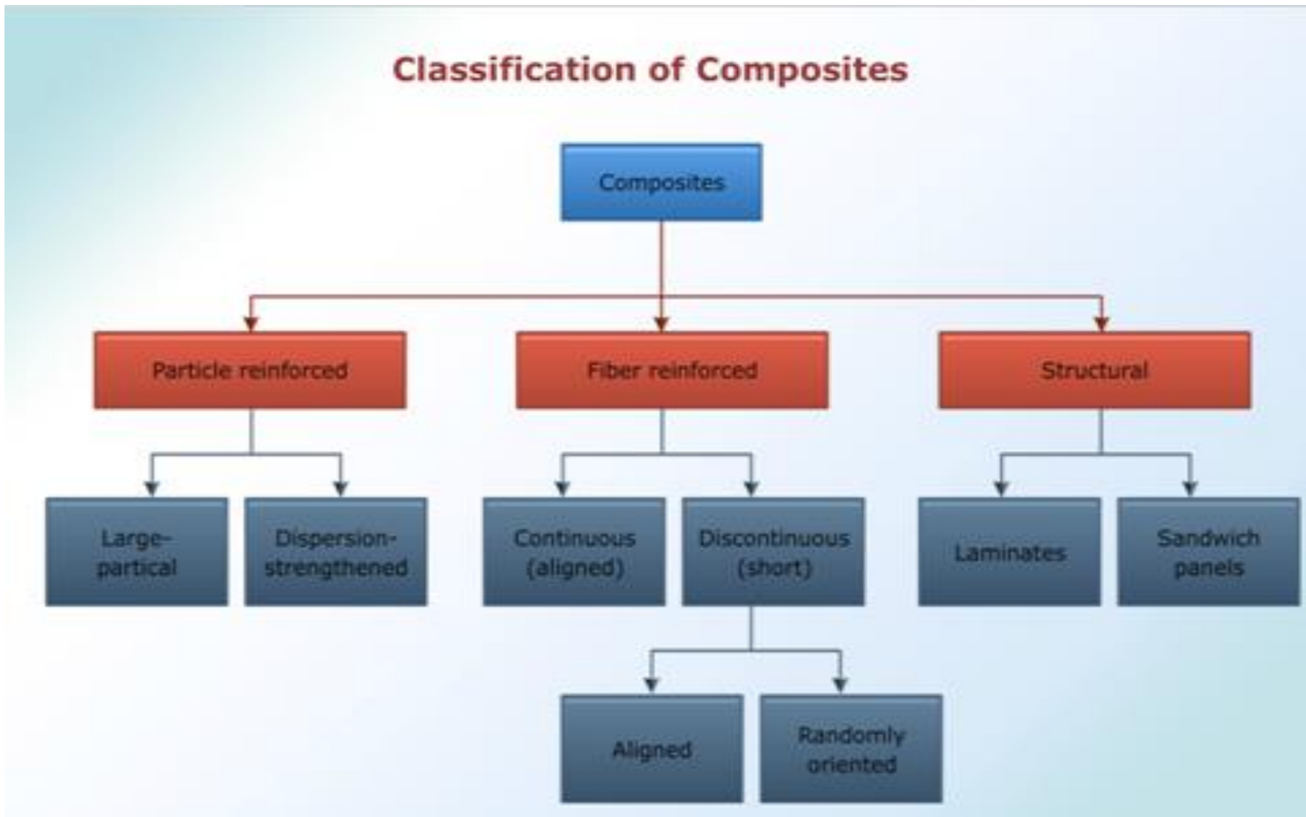
Ex: - Fiber glass, Reinferced plastics commonly used in house hold goods and in many industrial applications.

Their plastic alone is relatively weak& has low elastic modulus i.e., it bends and stretch easily. The glass fiber provides strength and stiffness; their modulus of elasticity may be sometimes more than that of plastics. Since glass fiber can with stand much higher tensile strength before yielding occurs. They take most of load when composite is stressed.

Metals, Ceramics, Glasses, Polymers and cement can be combined in composite materials to produce unique characteristics such as stiffness, toughness and high temperature strength.

Many composite materials are composed of just two phases one is termed as matrix which is continuous and the other phase often called the dispersed phase

Classification of composite materials:-



Manufacturing of composites

1. **Open Mold Processes**- some of the original FRP manual procedures for laying resins and fibers onto forms

2. Closed Mold Processes- much the same as those used in plastic molding

3. Filament Winding- continuous filaments are dipped in liquid resin and wrapped around a rotating mandrel, producing a rigid, hollow, cylindrical shape

- A polymer matrix composite (PMC) is a composite material consisting of a polymer imbedded with a reinforcing phase such as fibers or powders
- FRP composites can be designed with very high strength-to-weight and modulus-to-weight ratios
- These features make them attractive in aircraft, cars, trucks, boats, and sports equipment

Particle Reinforced Composite:-

The dispersed phase of particle reinforced composite is equi axed (Particle dimensions are approx same in all directions)

<u>Large particle Composite:-</u>

Fillers are added to some polymeric materials produces large particle composite. The fillers modified or improve the properties of materials and replace some of the polymers volume with less expensive fillers materials

Ex:-

1. Concrete is an example of large particle compsites.It is composed of cement and sanded gravels. The particles have a verity of geometry but they should be approximately the same dimensions in all in all directions (equi axed).

2. Particles should be small and evenly distributed thought matrix for effective reinforced. More over the volume fraction of the two phases influence the behavior.

3. Mechanical properties are enhanced with increasing the particulate content.

4. Large particles composites are utilized with 3 material types i.e., Metals ,Ceramics and polymers.

Example of ceramic metals composites are cermet, cementite carbide which are composed of extremely hard particles of a refractory carbide ceramics. Such as wc,Tic etc.... embedded in a matrix of metals such as **Cu** or **Ni** is the common cermet.These composites are widely used as a cutting tools.

Dispersed strengthen Composite:-

This type of composite contains small particulates with increses the strength of the composite by blocking the movement of dislocation.

Ex:-Sintered Aluminium Powder (SAP)

SAP has an Al matrix which contains op to 14% Al2O3.This composite is produced with powder metallurgy process where the powder are mixed compacted at high pressure and sintered together.

Sintering involves heating a material until the particles of the material fuse together only the particles are generally bonded together the whole doesn't melt.

Application:- Ag-cdo used as a electrical contact material

Pb-pbo used in battery plates

Ba-bao used in nuclear reactors & aerospace components

The high temp strength of Ni alloy may be enhanced significantly by the addition of about 3% volume of Thoria (Tho2) as finely dispersed particles. This material is known as Thoria dispersed Nickel.

Fiber Reinforced Composite:-

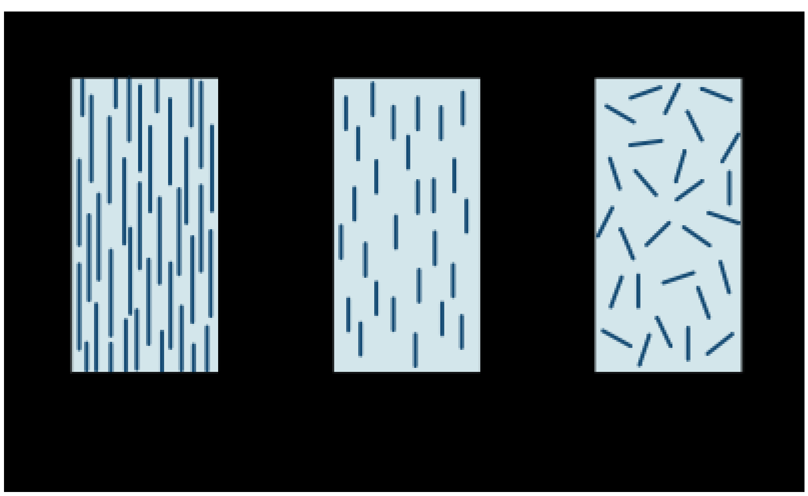


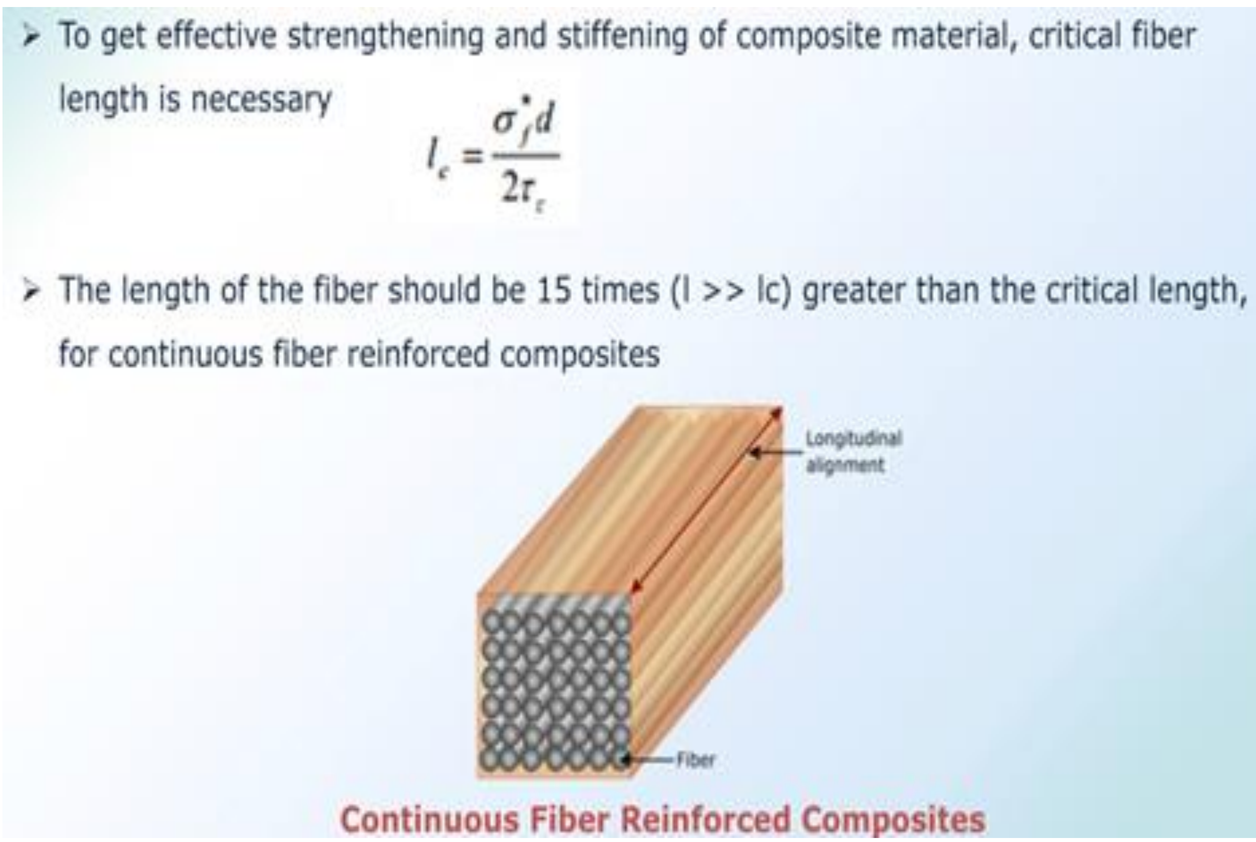
Fig: fiber Reinforced Composite

These are strong fibers embedded in a strong matrix produce products with high strength to weight ratio.

The matrix material transmits the load to the fibers, which absorbs the stress.

2. Fiber reinforced composite with exceptionally high specific strength and moduli have been produced that utilize low density fillers and matrix materials.

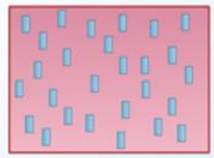
3.Some critical length is necessary for effective strengthening and stiffing the composite meterial.The critical lengths(lc) depends upon the fiber diameter(d) and its ultimate tensile change of fiber(sigma f) and matrix bond strength(Tc).



Continuous Fiber Reinforced Composites

2. DISCONTINOUS FRP:

- The fiber length in this, has the shorter lengths and the alliance between the matrix and fiber is given out at the fiber's end
- Based on the alignment it can be further subdivided
  - **Aligned:** In this composites, fibers are aligned parallel to each other. It is shown in the image.



Aligned

  - **Random:** In this composites, fibers are aligned randomly to each other as shown in the image.

Random

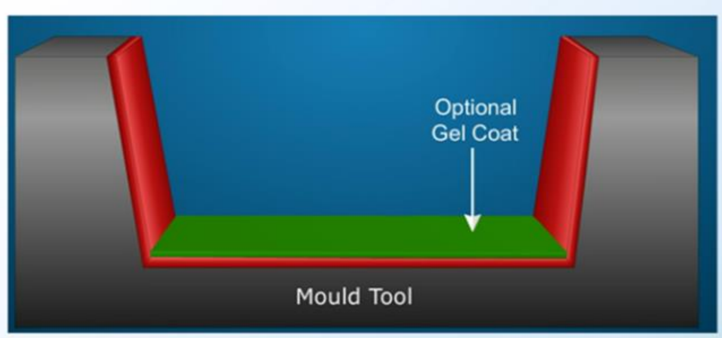
Fabrication of FRP: Fabrication processes of composites are

- Hand layup process
- Filament winding process
- Pultrusion process

Hand layup process

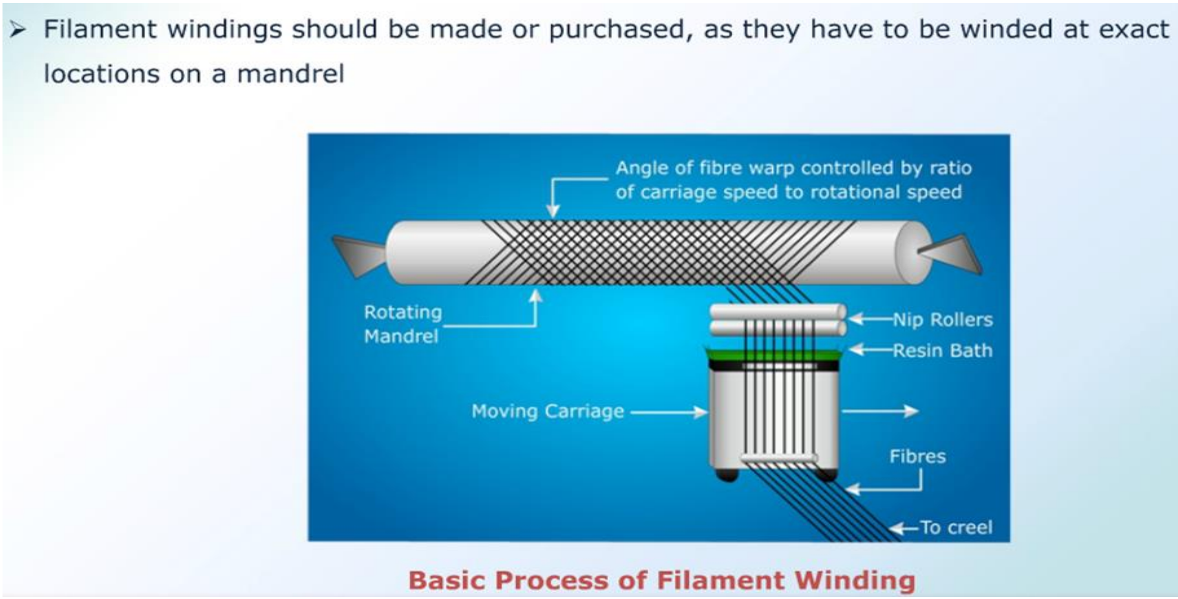
Hand Lay-up Process

- Hand lay-up is one of the simple production methods for composite
- The reinforcing material is placed in the mold for hand lay-up parts unless the composite is to be connected directly to another structure



Basic Process of Hand Lay-up

Filament Winding



Pultrusion

– Continuous fibers pulled through resin tank, then performing die & oven to cure

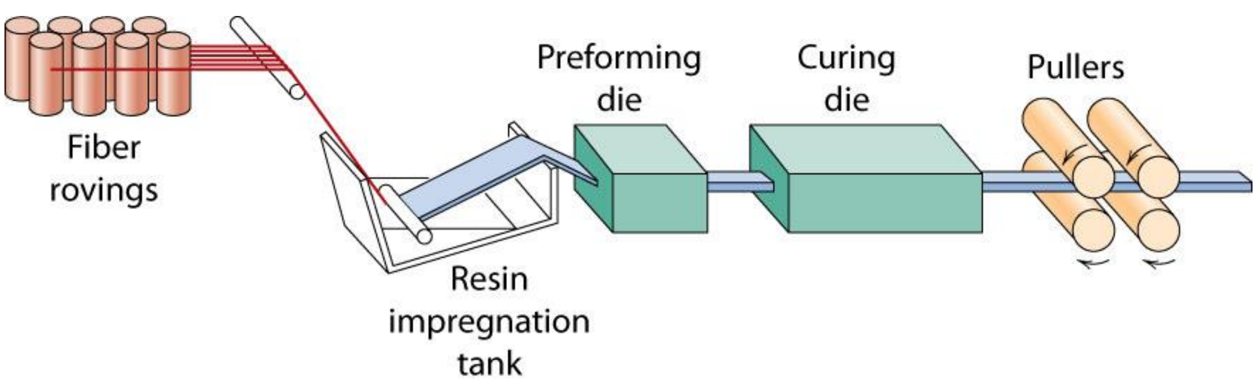
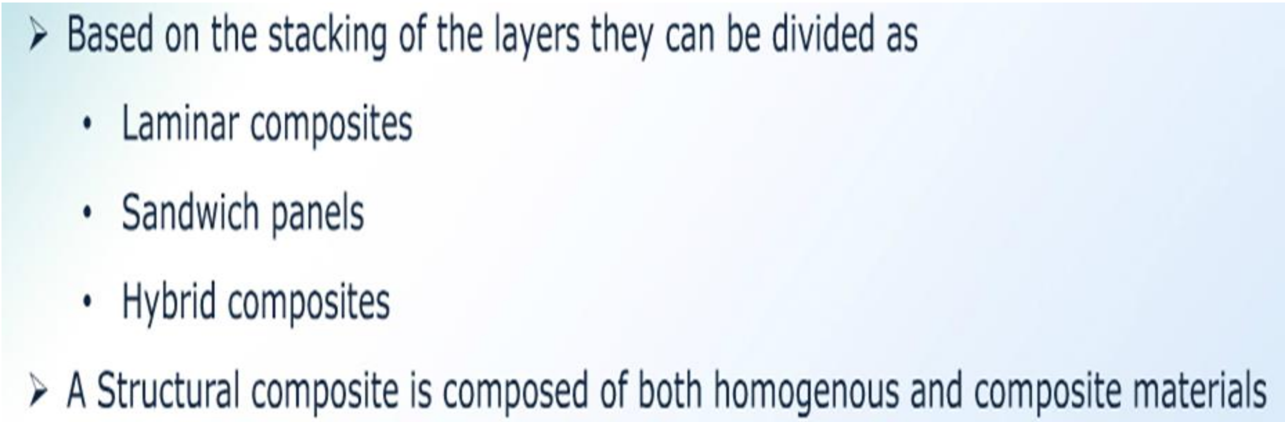
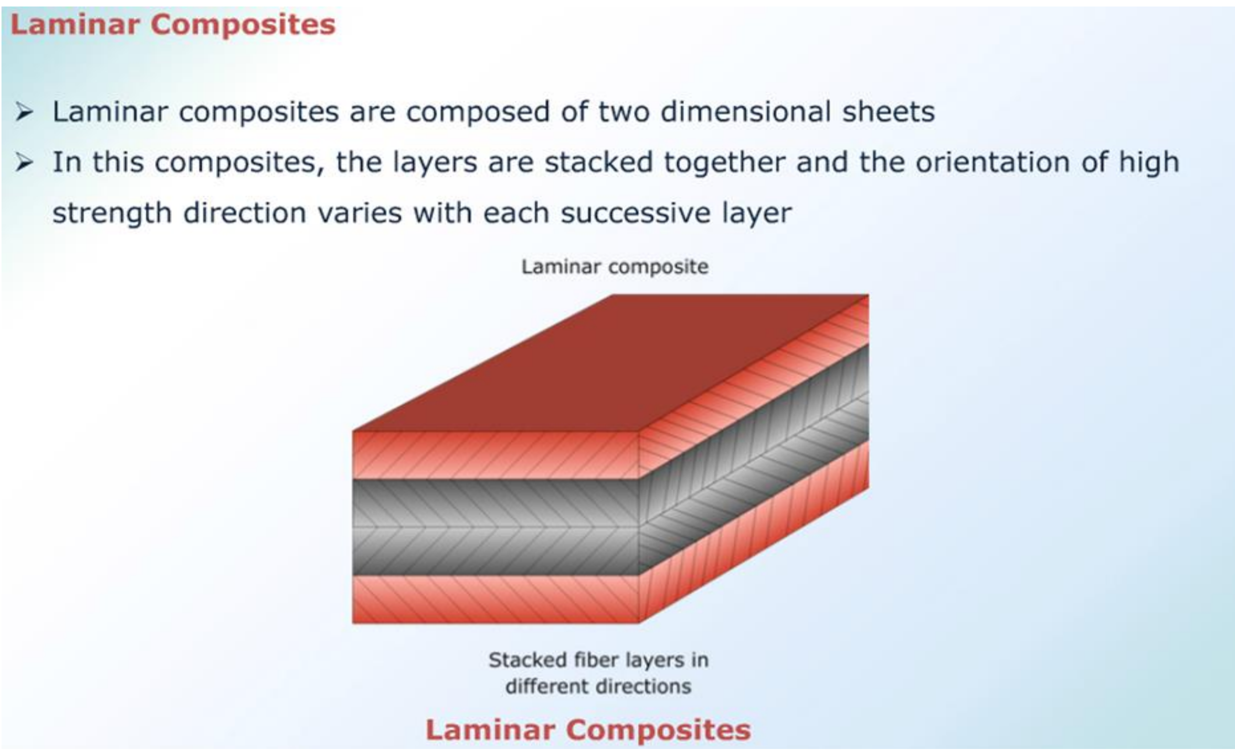


Fig: Pultrusion process

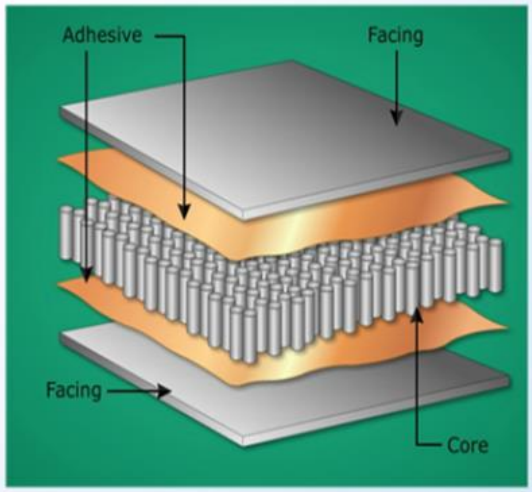


Laminar Composites



Sandwich panels

- In this composite, less dense material can separate the two strong outer sheets
- Layer of less dense material has lower hardness and less strength
- The faces bear most of the in-plane loading and also any transverse bending stress



Sandwich Panels

Hybrid composites

- They are obtained by using two or more different kinds of fiber in a single matrix
- Failure does not happen suddenly, when hybrid composites are stressed in tension

Types of composites

Cermets/Ceramal

The Cermet is an abbreviation for the "'ceramic" and "metal." A Cermets is a composite material composed of ceramic (Cer) and metallic (Met) materials. A Cermet is ideally designed to have the optimal properties of both a ceramic, such as high temperature resistance and hardness, and those of a metal, such as the ability to undergo plastic deformation. The metal is used as a binder for an oxide, boride, carbide, or alumina. Generally, the metallic elements used are nickel, molybdenum, and cobalt. Depending on the physical structure of the material, cermets can also be metal matrix composites, but cermets are usually less than 20% metal by volume.

It is used in the manufacture of resistors (especially potentiometers), capacitors, and other Electronic components which may experience high temperatures.

Some types of cermet are also being considered for use as spacecraft shielding as they resist the high velocity impacts of micrometeoroids and orbital debris much more effectively than more traditional spacecraft materials such as aluminum and other metals.

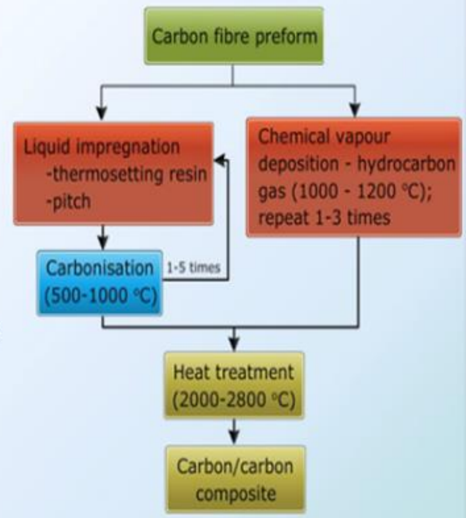
One application of these materials is their use in vacuum tube coatings, which are key to solar hot water systems. Cermets are also used in dentistry as a material for fillings and prostheses. Also it used in machining on cutting tools.

Cermets are one of the premier groups of particle strengthened composites and usually comprises ceramic grains of borides, carbides or oxides. The grains are dispersed in a refractory ductile metal matrix, which accounts for 20 to 85% of the total volume. The bonding between ceramic and metal constituents is the result of a small measure of mutual solutions.

Metal oxide systems show poor bonding and require additional bonding agents. Cermet Structures are usually produced using power metallurgy techniques. Their potential properties are several and varied depending on the relative volumes and compositions and of the metal and ceramic constituents. Impregnation of a porous ceramic structure with a metallic matrix binder is another method used to produce cermets. Cermets may be employed as coating in a power form. The power is sprayed through a gas flame and fused to a base material. A wide variety of cermets have been produced on a small scale, but only a few have appreciable value commercially.

Carbon-carbon composites

- Carbon-carbon composites can be produced in two basic ways
- Both involve the infiltration of a carbon-bearing fluid into the interstices between an array of carbon fibers
- In both cases, the main concern is achieving complete infiltration in a reasonably short time



Production Process of Carbon-Carbon Composites

Metal matrix composites (MMCs):

- Metal matrix composites (MMCs), consist of at least two chemically and physically distinct phases, suitably distributed to provide properties not obtainable with eithe the individual phases
- Fracture, high strength, toughness and hardness can be offered by metal matrix composites
- When metal matrix materials require high modulus reinforcements, then these composites offer high strength

Introduction

Although it is undoubtedly true that the high strength of composites is largely due to the fiber reinforcement, the importance of matrix material cannot be underestimated as it provides support for the fibers and assists the fibers in carrying the loads. It also provides stability to the composite material. Resin matrix system acts as a binding agent in a structural component in which the fibers are embedded. When too much resin is used, the part is classified as resin rich. On the other hand if there is too little resin, the part is called resin starved. A resin rich part is more susceptible to cracking due to lack of fiber support, whereas a resin starved part is weaker because of void areas and the fact that fibers are not held together and they are not well supported.

Matrix Selection

Thermodynamically stable dispersions are essential for the use of metal matrix composites for high temperature applications. This can be done by using an alloy dispersion system in which **solid state diffusivity**, **interfacial energies** and **elemental solubility** are minimized, in turn reducing coarsening and interfacial reactions. Aluminium and magnesium alloys are regarded as widely used matrices due to low density and high thermal conductivity. Composites with low matrix alloying additions result in attractive combinations of ductility, toughness and strength. In discontinuous reinforced metal matrix composites minor alloying elements, used in wrought alloys as grain refiners, are not required. These additions should be avoided since coarse inter-metallic compounds get formed during consolidation, thus, reducing the tensile ductility of the composite.

Role of matrix materials

The choice of a matrix alloy for an MMC is dictated by several considerations. Of particular importance is whether the composite is to be continuously or discontinuously reinforced. The use of continuous fibers as reinforcements may result in transfer of most of the load to the reinforcing filaments and hence composite strength will be governed primarily by the fiber strength. The primary roles of the matrix alloy then are to provide efficient transfer of load to the fibers and to blunt cracks in the event that fiber failure occurs and so the matrix alloy for continuously reinforced composites may be chosen more for toughness than for strength. On this basis, lower strength, more ductile, and tougher matrix alloys may be utilized in continuously reinforced composites. For discontinuously reinforced composites, the matrix may govern composite strength. Then, the choice of matrix will be influenced by consideration of the required composite strength and higher strength matrix alloys may be required.

Additional considerations in the choice of the matrix include potential reinforcement/matrix reactions, either during processing or in service, which might result in degraded composite performance; thermal stresses due to thermal expansion mismatch between the reinforcements and the matrix; and the influence of matrix fatigue behavior on the cyclic response of the composite. Indeed, the behavior of composites under cyclic loading conditions is an area requiring special consideration. In composites intended for use at elevated temperatures, an additional consideration is the difference in melting temperatures between the matrix and the reinforcements. A large melting temperature difference may result in matrix creep while the reinforcements remain elastic, even at temperatures approaching the matrix melting point. However, creep in both the matrix and reinforcement must be considered when there is a small melting point difference in the composite.

Functions of a Matrix

In a composite material, the matrix material serves the following functions:

- Holds the fibers together.
- Protects the fibers from environment.
- Distributes the loads evenly between fibers so that all fibers are subjected to the same amount of strain.
- Enhances transverse properties of a laminate.
- Improves impact and fracture resistance of a component.

Helps to avoid propagation of crack growth through the fibers by providing alternate failure path along the interface between the fibers and the matrix.

- Carry interlaminar shear.

The matrix plays a minor role in the tensile load-carrying capacity of a composite structure. However, selection of a matrix has a major influence on the interlaminar shear as well as in-plane shear properties of the composite material.

The interlaminar shear strength is an important design consideration for structures under bending loads, whereas the in-plane shear strength is important under torsion loads. The matrix provides lateral support against the possibility of fiber buckling under compression loading, thus influencing to some extent the compressive strength of the composite material. The interaction between fibers and matrix is also important in designing **damage tolerant structures**. Finally, the processability and defects in a composite material depend strongly on the physical and thermal characteristics, such as viscosity, melting point, and curing temperature of the matrix.

Desired Properties of a Matrix

The needs or desired properties of the matrix which are important for a composite structure are as follows:

- Reduced moisture absorption.
- Low shrinkage.
- Low coefficient of thermal expansion.
- Good flow characteristics so that it penetrates the fiber bundles completely and eliminates voids during the compacting/curing process.
- Reasonable strength, modulus and elongation (elongation should be greater than fibre).
- Must be elastic to transfer load to fibers.
- Strength at elevated temperature (depending on application).
- Low temperature capability (depending on application).
- Excellent chemical resistance (depending on application).
- Should be easily process able into the final composite shape.
- **Dimensional stability** (maintains its shape).

As stated above, the matrix causes the stress to be distributed more evenly between all fibers by causing the fibers to suffer the same strain. The stress is transmitted by shear process, which requires good bonding between fiber and matrix and also high shear strength and modulus for the matrix itself. One of the important properties of cured matrix system is its glass transition temperature (T) at which the matrix begins to soften and exhibits a decrease in mechanical properties. The glass transition temperature is not only an important parameter for dimensional stability of a composite part under influence of heat, but it also has effect on most of the physical properties of the matrix system at ambient temperature.

As the load is primarily carried by the fibers, the overall elongation of a composite material is governed by the elongation to failure of the fibers that is usually 1-1.5%. A significant property of the matrix is that it should not crack.

The function of the matrix in a composite material will vary depending on how the composite is stressed. For example, in case of compressive loading, the matrix prevents the fibers from **buckling** and is, therefore, a very critical part of the composite since without it; the reinforcement could carry no load. On the contrary, a bundle of fibers could sustain high tensile loads in the direction of the filaments without a matrix. Some of the physical properties of the matrix which influence the behavior of composites are:

- **Shrinkage** during cure,
- Modulus of elasticity,
- Ultimate elongation,
- Strength (tensile, compressive and shear), and
- **Fracture toughness**.

Factors considered for Selection of Matrix

In selecting matrix material, following factors may be taken into consideration:

- The matrix must have a mechanical strength commensurate with that of the reinforcement i.e. both should be compatible. Thus, if a high strength fiber is used as the reinforcement, there is no point using a low strength matrix, which will not transmit stresses efficiently to the reinforcement.
- 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.
- The matrix must be easy to use in the selected fabrication process.
- Smoke requirements.
- Life expectancy.
- The resultant composite should be cost effective.

The fibers are saturated with a liquid resin before it cures to a solid. The solid resin is then said to be the matrix for the fibers.

Advantages and Limitations of Composites Materials

Advantages of Composites

The advantages exhibited by composite materials, which are of significant use in aerospace industry are as follows:

• High resistance to fatigue and corrosion **degradation**.

• High 'strength or stiffness to weight' ratio. As enumerated above, weight savings are significant ranging from 25-45% of the weight of conventional metallic designs.

• Due to greater **reliability**, there are fewer inspections and structural repairs.

• Directional **tailoring capabilities** to meet the design requirements. The fibre pattern can be laid in a manner that will tailor the structure to efficiently sustain the applied loads.

• Fiber to fiber redundant load path.

• Improved dent resistance is normally achieved. Composite panels do not sustain damage as easily as thin gage sheet metals.

• It is easier to achieve smooth **aerodynamic profiles** for drag reduction. Complex double-curvature parts with a smooth surface finish can be made in one manufacturing operation.

• Composites offer improved **torsion stiffness**. This implies high whirling speeds, reduced number of intermediate bearings and supporting structural elements. The overall part count and manufacturing & assembly costs are thus reduced.

• High resistance to impact damage.

• Thermoplastics have rapid process cycles, making them attractive for high volume commercial applications that traditionally have been the domain of sheet metals. Moreover, thermoplastics can also be reformed.

• Like metals, thermoplastics have indefinite shelf life.

• Composites are **dimensionally stable** i.e. they have low thermal conductivity and low coefficient of thermal expansion. Composite materials can be tailored to comply with a broad range of thermal expansion design requirements and to minimize thermal stresses.

• Manufacture and assembly are simplified because of part integration (joint/fastener reduction) thereby reducing cost.

• The improved **weather ability** of composites in a marine environment as well as their corrosion resistance and durability reduce the down time for maintenance.

• Close tolerances can be achieved without machining.

• Material is reduced because composite parts and structures are frequently built to shape rather than machined to the required configuration, as is common with metals.

• Excellent heat sink properties of composites, especially Carbon-Carbon, combined with their lightweight have extended their use for aircraft brakes.

• Improved friction and wear properties.

• The ability to tailor the basic material properties of a Laminate has allowed new approaches to the design of **aero elastic flight structures**.

The above advantages translate not only into airplane, but also into common implements and equipment such as a graphite racquet that has inherent damping, and causes less fatigue and pain to the user.

Limitations of Composites

Some of the associated disadvantages of advanced composites are as follows:

- High cost of raw materials and fabrication.
- Composites are more brittle than wrought metals and thus are more easily damaged.
- Transverse properties may be weak.
- Matrix is weak, therefore, low toughness.
- Reuse and disposal may be difficult.
- Difficult to attach.
- Repair introduces new problems, for the following reasons:
  - Materials require refrigerated transport and storage and have limited shelf life.
  - Hot curing is necessary in many cases requiring special tooling.
  - Hot or cold curing takes time.
  - Analysis is difficult.
  - Matrix is subject to environmental degradation.

However, proper design and material selection can circumvent many of the above disadvantages.

New technology has provided a variety of reinforcing fibers and matrices those can be combined to form composites having a wide range of exceptional properties. Since the advanced composites are capable of providing structural efficiency at lower weights as compared to equivalent metallic structures, they have emerged as the primary materials for future use.

In aircraft application, advanced fiber reinforced composites are now being used in many structural applications, viz. floor beams, engine cowlings, flight control surfaces, landing gear doors, wing-to-body fairings, etc., and also major load carrying structures including the vertical and horizontal stabilizer main torque boxes.

Composites are also being considered for use in improvements to civil infrastructures, viz., earthquake proof highway supports, power generating wind mills, long span bridges, etc.

Comparison with Metals

Requirements governing the choice of materials apply to both metals and reinforced plastics. It is, therefore, imperative to briefly compare main characteristics of the two.

- Composites offer significant weight saving over existing metals. Composites can provide structures that are 25-45% lighter than the conventional aluminium structures designed to meet the same functional requirements. This is due to the lower density of the composites.

  Depending on material form, composite densities range from 1260 to 1820 kg/in^3 (0.045 to 0.065 lb/in^3) as compared to 2800 kg/in^3 (0.10 lb/in^3) for aluminium. Some applications may require thicker composite sections to meet strength/stiffness requirements, however, weight savings will still result.
- Unidirectional fibre composites have specific tensile strength (ratio of material strength to density) about 4 to 6 times greater than that of steel and aluminium.
- Unidirectional composites have specific -modulus (ratio of the material stiffness to density) about 3 to 5 times greater than that of steel and aluminium.
- **Fatigue endurance limit** of composites may approach 60% of their **ultimate tensile strength**. For steel and aluminium, this value is considerably lower.
- Fiber composites are more versatile than metals, and can be tailored to meet performance needs and complex design requirements such as **aero-elastic loading** on the wings and the vertical & the horizontal stabilizers of aircraft.
- Fiber reinforced composites can be designed with excellent structural **damping features**. As such, they are less noisy and provide lower vibration transmission than metals.
- High corrosion resistance of fiber composites contributes to reduce life- cycle cost.

- Composites offer lower manufacturing cost principally by reducing significantly the number of detailed parts and expensive technical joints required to form large metal Structural components. In other words, composite parts can eliminate joints/fasteners thereby providing parts simplification and integrated design.
- Long term service experience of composite material environment and **durability behavior** is limited in comparison with metals.