A Vivid Study of Composite Materials

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***Abstract* - A composite is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the parent material. The individual components remain separate and distinct within the finished structure. The new material may be preferred for many reasons: common examples include materials which are stronger, lighter, or less expensive when compared to traditional materials. As the composite materials possess great properties they are substituting various other conventional materials therefore, the research on composite materials must be developed further. Contemporary composites results from research and innovation from past few decades have progressed from glass fiber for automobile bodies to particulate composites for aerospace and a range other applications. This study has been undertaken to review the various Composite Materials both natural composited and fabricated composites with recent applications**

***keywords* - fiber, matrix, Laminates, Reinforcement, polymer composites.**

I. INTRODUCTION

A typical composite material is a system of materials composing of two or more materials on a macroscopic scale. Generally, a composite material is composed of reinforcement like fibers, particles, flakes, and/or fillers embedded in a matrix (polymers, metals, or ceramics). The matrix holds the reinforcement to form the desired shape while the reinforcement improves the overall mechanical properties of the matrix. When designed properly, the new combined material exhibits better strength than would each individual material.

Ironically, despite the growing familiarity with composite materials and ever-increasing range of applications, the term defines a clear definition. Loose terms like "materials composed of two or more distinctly identifiable constituents" are used to describe natural composites like timber, organic materials, like tissue surrounding the skeletal system, soil aggregates, minerals and rock. Composites that form heterogeneous structures which meet the requirements of specific design and function, instill with desired properties which limit the scope for classification. However, this drop is made up for, by the fact new types of composites are being innovated all the time, each with their own specific purpose like the filled, flake, particulate and laminar composites.

Fibers or particles embedded in matrix of another material would be the best example of modern-day composite materials, which are mostly structural. Various methods are inculcated to fabricate reinforcement into matrix.

Laminates are composite material where different layers of materials give them the specific character of a composite material having a specific function to perform. Fabrics have no matrix to fall back on, but in them, fibers of different compositions combine to give them a specific character. Reinforcing materials generally withstand maximum load and serve the desirable properties.

Further, though composite types are often distinguishable from one another, no clear determination can be really made. No specific proportion of the reinforcement is derived to get desired specific composite material. To facilitate definition, the accent is often shifted to the levels at which differentiation take place viz., microscopic or macroscopic.

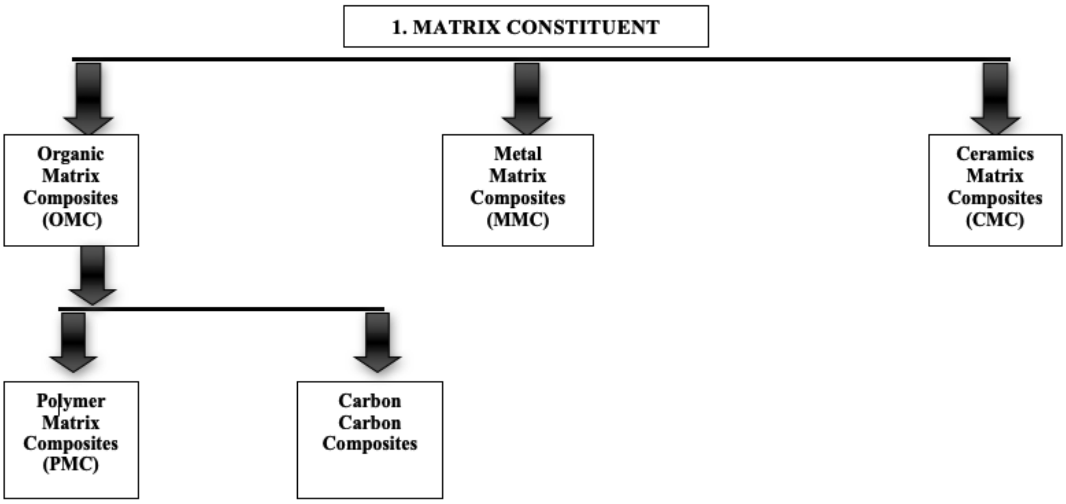
In matrix-based structural composites, the matrix serves two paramount purposes viz., binding the reinforcement phases in place and deforming to distribute the stresses among the constituent reinforcement materials under an applied force.

II. ADVANCEMENT IN COMPOSITE MATERIALS

In the 1970s the composites industry began to mature. Better plastic resins and improved reinforcing fibers were developed. Carbon fibers were also developed around this time; it has since been replacing metal as the new material of choice. The composite industry is still evolving, with much of the growth is now focused around Renewable energy Wind turbine blades are constantly pushing the limits on size and are requiring advanced materials, designs, and manufacturing. In contrast to metallic alloys, each material retains its separate chemical, physical, and mechanical properties. The two constituents are Reinforcement and a matrix.

III. CLASSIFICATION OF COMPOSITES

I. Composite materials are commonly classified with respect to **Matrix Constituent & Reinforcement form**:



II. Based on the form of reinforcement, common composite materials can be classified as follows:

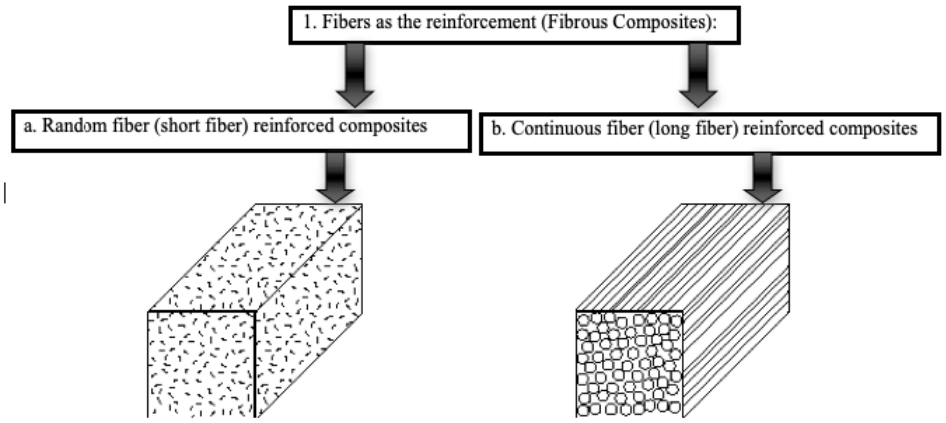


Figure: 3.1

2. Particles as the reinforcement (Particulate composites):

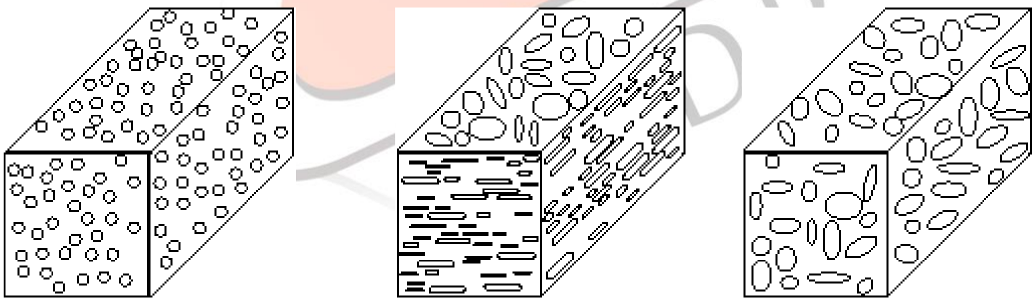


Figure: 3.2 Figure: 3.3 Figure: 3.4

3. Flat flakes as the reinforcement (Flake composites):
4. Fillers as the reinforcement (Filler composites):

IV. VIVID STUDY OF MATRIX MATERIALS

Some composites provide interphases when surfaces dissimilar constituents interact with each other. Choice of fabrication method depends on matrix properties and the effect of matrix on properties of reinforcements. One of the prime considerations in the selection and fabrication of composites is that the constituents should be chemically inert non-reactive. Figure 4.1 helps to classify matrices.

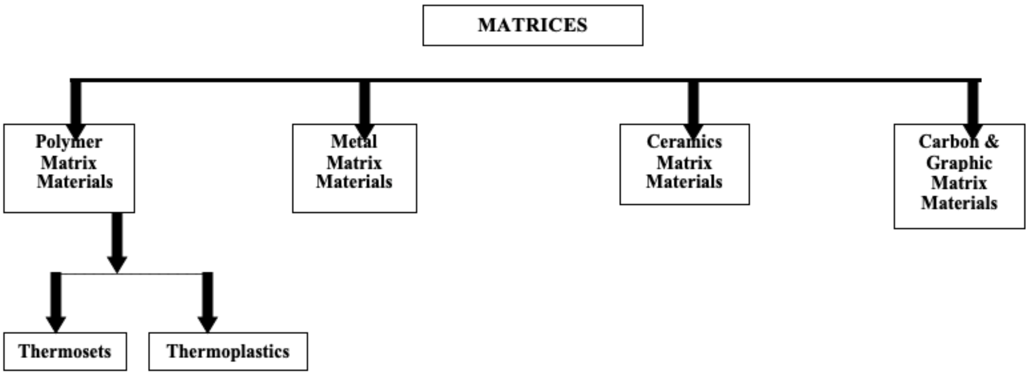


Table 4.1: Matrix Material Characteristics

Sr. No.	Name of the Material	Prominent distinctiveness
1.	Polymer Matrix - Thermosets	1.well-bonded three-dimensional molecular structure after curing 2. They decompose instead of melting on hardening 3. Thermosets are very flexible 4. Thermosets find wide ranging applications in the chopped fiber composites
2.	Polymer Matrix - Thermoplastics	1. Have one- or two-dimensional molecular structure 2. The process of softening at elevated temperatures can reversed to regain its properties during cooling. 3. Resins reinforced with thermoplastics now comprised an emerging group of composites. 4. They are used in automotive control panels, electronic products encasement etc.
3.	Metal Matrix Materials	1. High strength, fracture toughness and stiffness are offered by metal matrices than those offered by their polymer counterparts. 2. They can withstand elevated temperature in corrosive environment than polymer composites. 3. Most metals and alloys make good matrices. 4. Only light metals are responsive, with their low density proving an advantage. 5. Titanium, Aluminium and magnesium are the popular matrix metals currently in vogue. 6. They are particularly useful for aircraft applications. 7. Most metals, ceramics and compounds can be used with matrices of low melting point alloys.
4.	Ceramic Matrix Materials	1. Ceramics can be described as solid materials which exhibit very strong ionic bonding. 2. High melting points, good corrosion resistance, stability at elevated temperatures and high compressive strength, render ceramic-based matrix. 3. Ceramics possesses high modulus of elasticity and low tensile strain. 4. Ceramics have caused the failure of attempts to add reinforcements to obtain strength improvement. 5. The use of reinforcement with high modulus of elasticity may take care of the problem to some extent and presents pre-stressing of the fiber in the ceramic matrix is being increasingly resorted to as an option.
5.	Carbon- Carbon Matrix Materials	1. This carbon-carbon composite is fabricated through compaction of carbon or multiple impregnations of porous frames with liquid carboniser precursors and subsequent pyrolization. 2. Carbon-carbon composites are not be applied in elevated temperatures, as many composites have proved to be far superior at these temperatures. 3. Their capacity to retain their properties at room temperature as well as at temperature in the range of 2400ºC and their dimensional stability make them the oblivious choice in a garnut of applications related to aeronautics, military, industry and space.
6.	Glass Matrices	1. Glass matrix composite with high strength and modulus can be obtained and they can be maintained upto temperature of the order of 650ºC. 2. Composites with glass matrices are considered superior in dimensions to polymer or metal system, due to the low thermal expansion behaviour.

V. VIVID STUDY OF REINFORMENT MATERIALS

Reinforcements for the composites can be fibers, fabrics particles or whiskers. Fibers are essentially characterized by one very long axis with other two axes either often circular or near circular. Particles have no preferred orientation and so does their shape. Whiskers have a preferred shape but are small both in diameter and length as compared to fibers. Figure 5.1 shows types of reinforcements in composites.

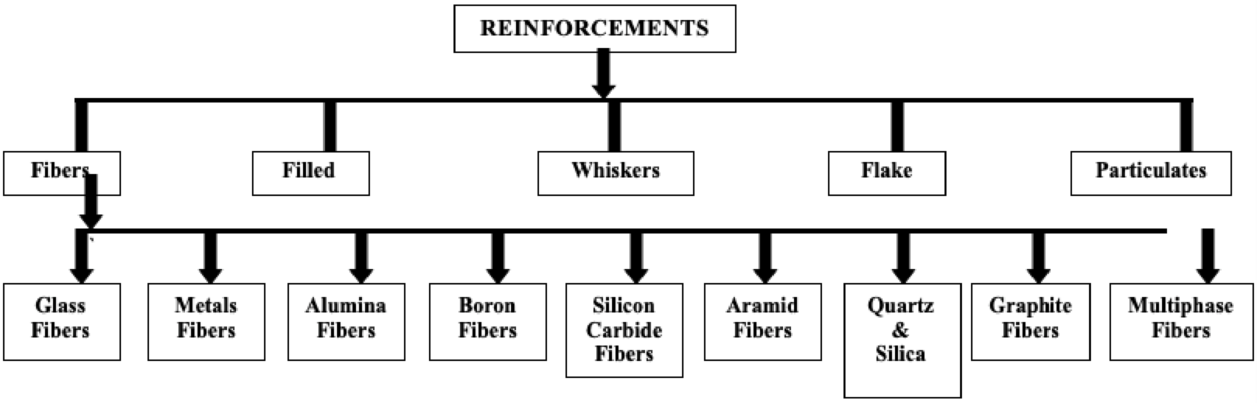


Figure 5.1

Table 4.2: Reinforcement Material Characteristics

Sr. No.	Name of the Material	Prominent distinctiveness
1.	Glass Fibers	1. Glass fibers, as they are inexpensive, easy to manufacture and possess high strength and stiffness with respect to the plastics with which they are reinforced. 2. Their low density, resistance to chemicals, insulation capacity are other bonus characteristics. 3. One major disadvantage in glass is that it is prone to break when subjected to high tensile stress for a long time. 4. Glass fibers are available in the form of mates, tapes, cloth, continuous and chopped filaments, roving and yarns.
2.	Metal Fibers	1. They are easily produced using several fabrication processes and are more ductile, apart from being not too sensitive to surface damage and possess high strengths and temperature resistance. 2. Their weight and the tendency to react each other through alloying mechanisms are major disadvantages. 3. Metal wires, of the continuous version, also reinforce plastics like polyethylene and epoxy. Such combinations ensure high strength, light weight and good fatigue resistance. 4. Better flexural properties are observed in some metal fibers reinforced plastic composites which also offer improved strength and weight, than glass fibers. 5. Their poor tolerance of high temperature and the resultant steep variations of thermal expansion coefficient with the resins are a discouragement that limits their their application.
3.	Alumina Fibers	1. Alumina aluminum oxide fibers, basically developed for use in metal matrices are considered a potential resin-matrix composite reinforcement. 2. It offers good compressive strength rather than tensile strength. 3. It's important property is it's high melting point of about 2000ºC and the composite can be successfully used at temperature up to about 1000ºC. 4. Magnesium and aluminum matrices frequently use alumina fiber reinforced composites as they do not damage the fiber even in the liquid state.
4.	Boron Fibers	1. Boron is coated on a substance which forms the substrate, usually made of tungsten. 2. They are known for their remarkable stiffness and strength. 3. Boron coated carbons are much cheaper to make than boron tungsten fiber. But is low modulus of elasticity often works against it.
5.	Silicon Carbide Fibers	1. Elevated temperature performance and the fact that they reported only a 35% loss of strength at 1350ºC are their best qualities. 2. Silicon carbide-tungsten and silicon carbide-carbon have both been seen to have very high stress-rupture strength at 1100ºC and 1300ºC. 3. Silicon carbide-tungsten fibers are dense compared to boron-tungsten fibers of the same diameters. 4. They are prone to surface damage and need careful, delicate handling, especially during fabrication of the composite 5. Silicon carbide on carbon substrates have several advantages, viz. no reaction at high temperature, being lighter than silicon carbide tungsten and possessing tensile strengths and modulus that is are often better than those of silicon carbide-tungsten and boron fibers.
6.	Aramid Fibers	1. Aramid fibers are made aromatic polyamides which are long polymeric chains and aromatic rings. 2. They are structures in which six carbon s\atoms are bonded to each other and to combinations of hydrogen atoms. 3. Aramids have high tensile strength, high modulus and low weight. Impact-resistant structures can be produced from aramids. 4. The density of aramid fibers is less than that of glass and graphite fibers.

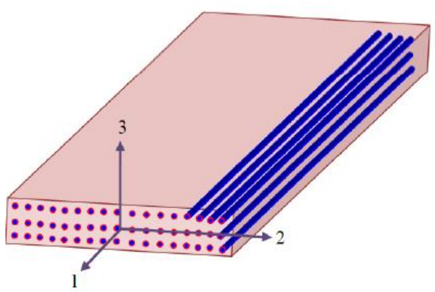
		5. They are fire resistant apart from being high-temperature resistant and unaffected by organic solvents fuels. 6. Aramid fibers have a negative coefficient of thermal expansion in the fiber direction and failure of aramid fibers is unique. 7. When they fail, the fibers break into small fibers, which are like fibers within the fibers. This unique failure mechanism is responsible for high strength.
7.	Quartz & Silica Fibers	1. The glass-types typically contain about 50 to 70% silica. 2. Silica glass is a purer glass fiber that can be made by treating fiberglass in an acid bath, which removes all impurities without affecting the silica. 3. Quartz is even more pure, and quartz fibers are made from natural quartz crystals that contain 99.9% silica, possessing nearly all the properties of pure solid quartz. 4. They are highly elastic and can be stretched to 1% of their length before break point. Both silica and quartz are not affected by acid attacks and are resistant to moisture. 5. Owing to their thermal properties, silica and quartz are the natural choice as fibers in several applications. They have good insulting properties and do not melt at temperature up to 1600ºC. 6. They have a low thermal expansion coefficient which makes them withstand high temperatures.
8.	Graphite Fibers	1. Element analysis of poly-acrylo-nitrile (PAN) base carbon fibers show that they consist of 91 to 94% carbon. But graphite fibers are over 99% carbon. The difference arises from the fact that the fibers are made at different temperatures. 2. PAN-based carbon cloth or fiber is produced at about 1320ºC, while graphite fibers and cloth are graphitised at 1950 to 3000ºC. 3. The properties of graphite remain unchanged even at high temperatures, but its willingness to react readily with most metals at the fabrication stage or during use at very high temperatures is often a stumbling block. 4. Graphite fibers are some of the stiffer fibers known. The stiffness of the fiber is as high as the graphite content. But a major drawback is that stiffness and strength are inversely proportional to each other. 5. The best glass fibers are far less expensive than the cheapest, lowest quality of graphite, and in PAN-base fibers, other raw materials too are equally expensive. 6. The carbonization and graphitisation are time-consuming, apart from demanding excessive energy, materials and close controls throughout the process.
9.	Multiphase Fibers	1. Spoolable filaments made by chemical vapour deposition processes are usually the multiphase variety and they usually comprise materials like boron, silicon and their carbides formed on surface of a very fine filament substrate like carbon or tungsten. 2. A poly-phase fiber is a core-sheath fiber consisting of a poly-crystalline core.
10.	Whiskers	1. Single crystals grown with nearly zero defects are termed whiskers. 2. They are usually discontinuous and short fibers of different cross sections made from several materials like graphite, silicon carbide, copper, iron etc. Typical lengths are in 3 to 55 N.M. ranges. 3. Whiskers can have extraordinary strengths upto 7000 MPa.

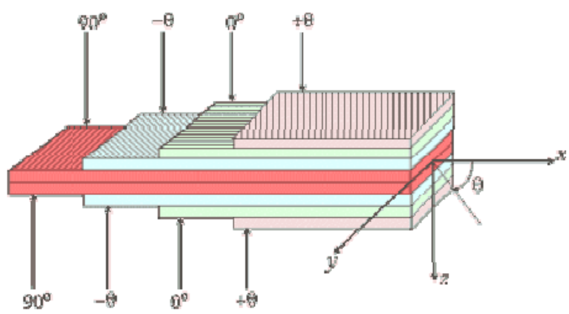
VI. SOLIDIFIED COMPOSITES & APPLICATIONS.

I. Layered composites: Layer, Lamina any of the term is used, Ply

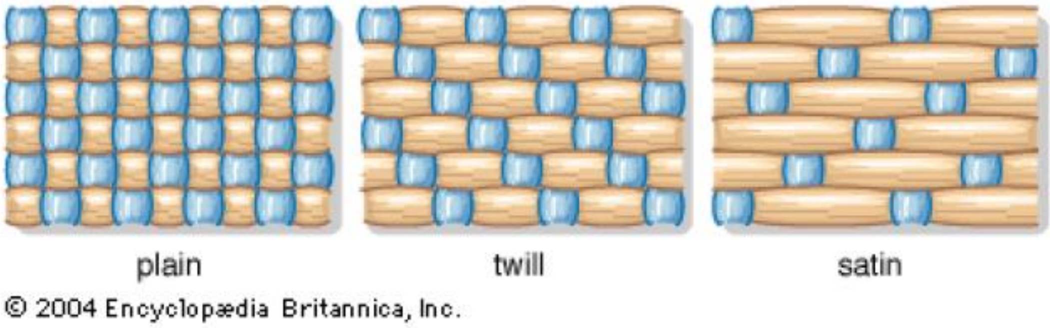
Axial – along fibre length (1)
Transverse – perpendicular to fibre length
2 – in-plane transverse
3 – out of plane transverse

II. Layered composites: Laminate





III. Woven Bi-directional Composite: Three types of Weave

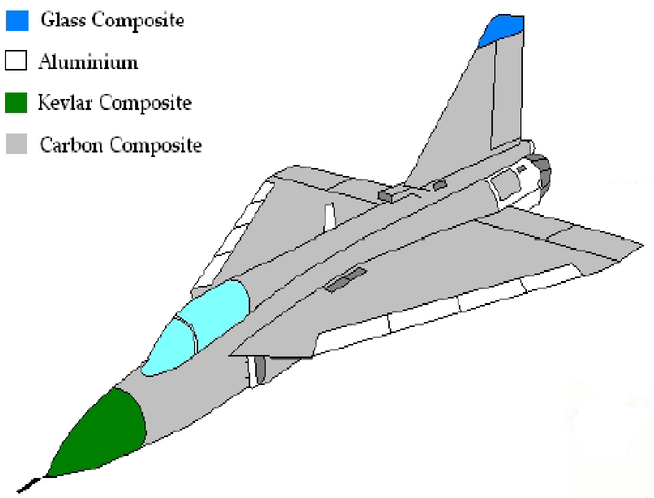


Composite materials are commonly classified at following two distinct levels:

- The first level of classification is usually made with respect to the matrix constituent. The major composite classes include Organic Matrix Composites (OMCs), Metal Matrix Composites (MMCs) and Ceramic Matrix Composites (CMCs). The term organic matrix composite is generally assumed to include two classes of composites, namely Polymer Matrix Composites (PMCs) and carbon matrix composites commonly referred to as carbon-carbon composites.
- The second level of classification refers to the reinforcement form - fibre reinforced composites, laminar composites and particulate composites. Fibre reinforced composites can be further divided into those containing discontinuous or continuous fibres.
- Fibre Reinforced Composites are composed of fibres embedded in matrix material. Such a composite is considered to be a discontinuous fibre or short fibre composite if its properties vary with fibre length. On the other hand, when the length of the fibre is such that any further increase in length does not further increase, the elastic modulus of the composite, the composite is considered to be continuous fibre reinforced. Fibres are small in diameter and when pushed axially, they bend easily although they have very good tensile properties. These fibres must be supported to keep individual fibres from bending and buckling.
- Laminar Composites are composed of layers of materials held together by matrix. Sandwich structures fall under this category.
- Particulate Composites are composed of particles distributed or embedded in a matrix body. The particles may be flakes or in powder form. Concrete and wood particle boards are examples of this category.

APPLICATIONS OF COMPOSITE MATERIALS:

Aerospace: Use of composites in LCA Tejas

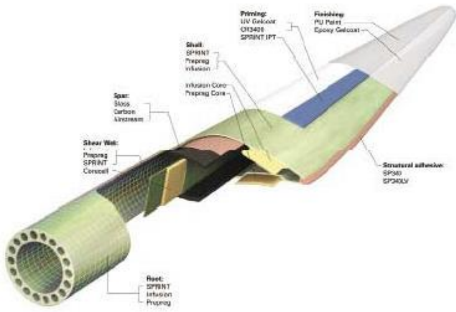


Composites in LCA

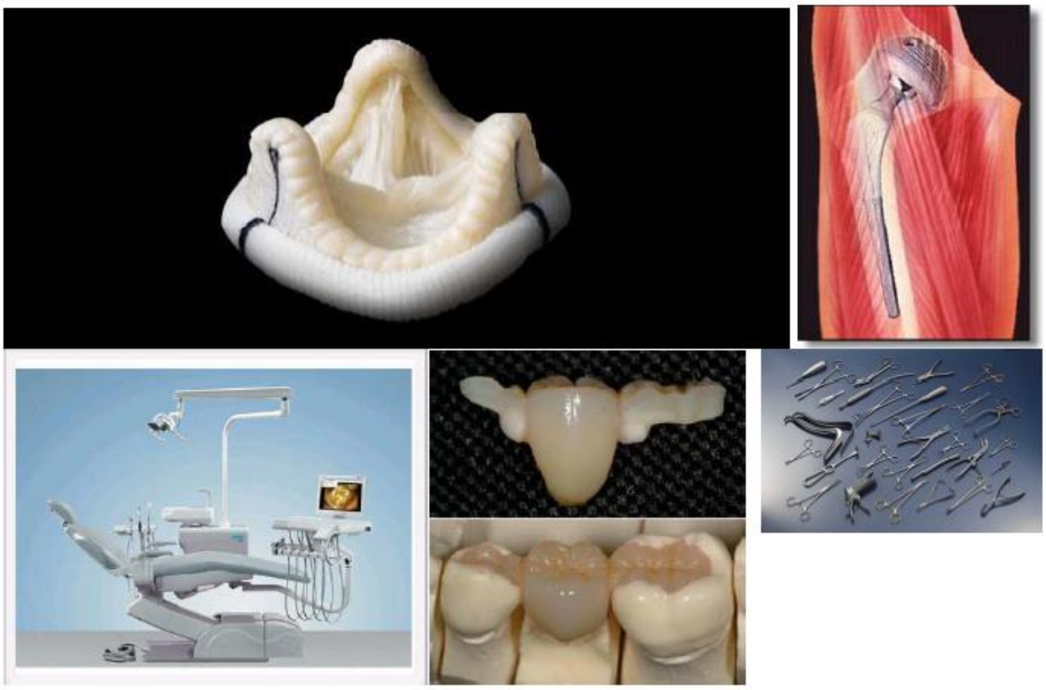
Automobile/Transportation:

Sports:

Wind Energy:



Medical:



Civil/Infrastructure:

VII. MERITS AND DEMERITS OF COMPOSITES

MERITS

1. High resistance to fatigue and corrosion degradation.
2. 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.
3. Due to greater reliability, there are fewer inspections and structural repairs.
4. 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.
5. Fibre to fibre redundant load path.
6. 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.
7. Composites offer improved torsional 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.

8. 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 minimise thermal stresses.
9. Manufacture and assembly are simplified because of part integration (joint/fastener reduction) thereby reducing cost.
10. The improved weather ability of composites in a marine environment as well as their corrosion resistance and durability reduce the down time for maintenance.
11. Close tolerances can be achieved without machining.
12. 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.
13. Excellent heat sink properties of composites, especially Carbon-Carbon, combined with their lightweight have extended their use for aircraft brakes.
14. Improved friction and wear properties.
15. The ability to tailor the basic material properties of a Laminate has allowed new approaches to the design of aeroelastic flight structures.

DEMERITS

Some of the associated demeritsof advanced composites are as follows:

1. High cost of raw materials and fabrication.
2. Composites are more brittle than wrought metals and thus are more easily damaged.
3. Transverse properties may be weak.
4. Matrix is weak, therefore, low toughness.
5. Reuse and disposal may be difficult.
6. Difficult to attach.
7. Analysis is difficult.
8. Matrix is subject to environmental degradation.

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