M-Kem

Composites

Our modern technologies, many a times, demand materials with unusual and extraordinary combination of properties that cannot be provided by the conventional metal alloys, ceramics and polymeric materials. This is particularly true for materials required for aerospace, under water and transportation applications. The ~~ever~~ ever increasing demand for special materials having unusual combination of properties (low density, stiffness, high strength, abrasion resistance, impact resistance, corrosion resistance) for use in our modern technologies is responsible for the development of composite materials.

A composite may be defined as any multiphase material that exhibits a significant proportion of the properties of both the constituent materials. Scientists and engineers have ingeniously designed various composites materials by the combination of metals, ceramics and polymers to produce new generation of extraordinary materials having combination of superior mechanical characteristics such as toughness, stiffness and high temperature strength. A composite, in the present context, is an artificially prepared multiphase material in which the chemically dissimilar phases are separated by a distinct interface.

Constituents of composites:

Two essential constituents of composites are; one is called matrix phase ~~and~~ which continuous and surrounds the other phase called the dispersed phase.

1. Matrix phase is the continuous body constituent, which encloses the composite and give it its bulk form. Matrix phase may be metal, ceramics or Polymer. Composites using these matrix are known as metal matrix composites, ceramic matrix composites and polymer matrix composites respectively. Polymer matrix materials used in composites are epoxy, polyamide (nylons), Phenolics, Silicons and polysulphones. Since some ductility is essential, only metals and and polymers are used as the matrix materials. Metals like Al and Cu and commercial thermoplastic and thermosetting polymers are generally used as the matrix materials.

Function of matrix materials:

(i) Binds the dispersed phase together

(ii) acts as medium to transmit and distribute ~~and~~ an externally applied load to the dispersed phase.

(iii) protects the dispersed phase from chemical action and keep in proper position and orientation during the application loads.

(iv) Prevents propogation of brittle cracks due to its plasticity and softness.

Requirement of a good matrix ~~mat~~ phase: It should be ductile and corrosion resistant and possess high bonding strength between matrix and dispersed phase.

Dispersed Phase: It is the structural constituent, which determine the internal structure of of composite. ~~Impor ant~~ Important dispersed phases of composites are,

- Fibre - It is a long and thin filament at any polymer, metal or ceramic having high length to diameter ratio.

- Particulates :- They are hard solid material (metallic or non-metallic).
- Flakes : are thin solid having a two-dimensional geometry e.g. mica flakes. (They are used in electrical and thermal insulating appliances.
- Whiskers :- They are thin strong filaments or fibers made by growing a crystal e.g of graphite, silicon carbide, aluminium oxide. Usually, they are in several mm in length and several microns in diameter or thickness. Perfect whiskers possess much higher strength than in bulk.

~~Rake up~~ Types of composites :-

A) Fibre-reinforced composites.

B). Particulate-composites.

C) Layered composites.

Layered composites :- They are extensively employed to many familiar applications. For e.g. Plywood.

PLYWOOD :- It is a laminated composite of thin layers of wood with alternate layers glued together so that the grain of each layer is at right angles of its neighbour, stainless steel cooling vessel with a copper clad bottom, stainless steel bonding on both sides of copper core etc. The properties of these composites depends upon the properties of the constituents, and their geometrical design.

→ Layered composites, in general, possess high strength in both directions of reinforcement, but their shear strength is comparatively low.

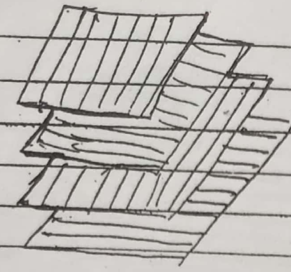
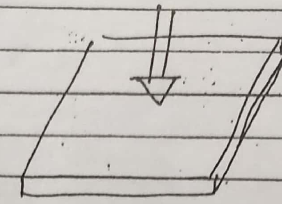


fig. The stacking of successive oriented, fibre reinforced layers for a laminar composite.



Reinforced concrete construction (R.C.C)

Concrete is a building and structural material, obtained by mixing a binding material (cement or lime), inert mineral aggregates (sand, crushed stone, gravel, broken brick, slag etc.) and water in a suitable proportion and which can be readily worked or ~~moulded into almost~~ any desired shape and when set, it is compact, strong and durable.

RCC :- Plain concrete has a great compressive strength, but little ability to withstand tension. Consequently, structures which are required to bear tensile stresses are reinforced (or strengthened) by embedded steel bars or rods and metal ~~meshes~~ meshes in such a way that the tension is taken ~~b~~ up by the steel; while the concrete carries the compression. This combination of steel and concrete produces structure, called reinforced concrete construction (R.C.C), which can bear all types of loads.

...rced concrete work is mostly used in floor-beams, ...s, lintels, girders, arches, slabs, bridges, etc.

Advantages of R.C.C. over plain concrete:-

(1) R.C.C. is easier to make and cast into any desired shapes, which can bear all types of loads.

(2) It possesses greater rigidity, moisture and fire resistance.

(3) Steel reinforcement also tends to distribute the shrinkage cracks, thus preventing the formation of large cracks.

(4) It's maintenance cost is practically negligible.

Scanned by CamScanner

Advantageous characteristics of composites:

Important advantages of composite materials over the conventional materials (metals, polymers and ceramics) are;

(i) higher specific strength (ii) lower specific gravity (iii) high specific stiffness (iv) maintain strength, even upto high temperatures. (v) better toughness, impact and thermal shock resistance. (vi) cheaply and easily fabricable. (vii) better creep and fatigue strength (viii) lower electrical conductivity (ix) lower thermal expansion and (x) better corrosion and oxidation-resistance.

Applications of composites:

(i) In automobile industries, transportation industries, turbine engines, wire drawing dies, valves, pump parts, ~~spray nozzles, storage tanks, fabrication of roof and~~ floors, furniture, sport goods (lawn tennis rackets), high speed machinery etc.

(ii) Marine applications like propellers, shafts, hulls, spars (for racing boats), and other ship parts.

(iii) Aeronautical applications like components of rockets, aircrafts, ~~Gbatsn~~ helicopters, missiles etc.

(iv) communication antennae, electronic circuit boards

(v)

Scanned by CamScanner

14. Mention some of the characteristics of ceramics.

Ans: Some of the basic properties of ceramics are high hardness, brittleness, have wear resistance, high compressive strength, good thermal insulation, low electrical conductivity, chemically inactive.

15. What are the main compositions of engineering ceramics?

Ans: Alumina, zirconia, Carbides, borides, nitrides, silicides, Particulate reinforced combinations of oxides and non-oxides.

16. Why ceramics doesn't have the corrosion tendency.

Ans: Most of the ceramics have good chemical resistance. The driving force for corrosion of a metal is the tendency to back to their native states such as oxides, nitrides or sulphides. So there is little driving force for corrosion.

Descriptive questions

1. What are ceramics? Briefly write the classification of ceramic materials.
2. What are the different structures of the ceramic compounds? Explain with neat sketches and examples.
3. What are the factors controlling the properties of the ceramics? Explain how they change with changing composition and compound along with suitable examples.
4. Write notes on the following :
   a) Advanced ceramics
   b) Mechanical properties of ceramics
   c) Industrial applications of ceramics

10 Composite Materials

10.1 Introduction

Composite materials (or ***composites*** for short) are a system of engine materials made from two or more constituent materials that have quite diffe properties (mixed and bonded) on a macroscopic scale with significantly diffe physical or chemical properties. The constituents remain separate and distinct wi the finished structure.

If the composition occurs on a microscopic scale (molecular level), the material is then called an alloy for metals or a polymer for plastics.

Composites exist in nature. A piece of wood is a composite, with long fi of cellulose (a very complex form of starch) held together by a much weaker substa called lignin. Cellulose is also found in cotton and linen, but it is the binding po of the lignin that makes a piece of timber much stronger than a bundle of cot fibres. Like wood, bone is also an example of natural composite constructed by processes of nature.

Not a new idea

Humans have been using composite materials for thousands of years. T mud bricks for example. A cake of dried mud is easy to break by bending, which p a tension force on one edge, but makes a good strong wall, where all the forces compressive. A piece of straw, on the other hand, has a lot of strength when i stretched but almost none when crumpled up. But if pieces of straw are embed i block of mud and dried hard, the resulting mud brick resists both squeezing a tearing and makes an excellent building material. More technically, it has both go compressive strength and good tensile strength.

SOME TYPICAL COMPOSITES

Serial No.	Class	Example	Applications
1	Metal- matrix composite	(i) Aluminium alloy (matrix)- Boron fiber (reinforcement) (ii) Super alloy(matrix)- Tungsten metal fiber (reinforcement) (iii)Cermets[Co or Ni (matrix) and WC or TiC particle (reinforcement), White cast iron	(i) Space shuttle orbiter (ii) Turbine engine Cutting tool
2	Ceramic-matrix com-posite	(i) SiC whisker- reinforced alumina (matrix) (ii) Concrete	(i) Cutting tool inserts for hard metal alloys (ii) Construction
3	Polymer-matrix com-posite	(i) Glass fiber reinforced polymer (GFRP) (ii) Carbon fiber reinforced polymer (CFRP) (iii) Aramid fiber reinforce-ment polymer	(i) Automotive and marine bodies, storage contain-ers, industrial flooring etc. (ii) Aircraft structural components, fixed wing and helicopters, pres-sure vessel etc (iii) Ballistic products, sporting goods, tires, automotive break and clutch linings etc
4	Carbon-matrix com-posite	(i) Carbon –carbon composite	(i) Rocket motors, as friction materials in aircrafts, high perfor-mance automobile, components for ad-vanced turbine etc.
5	Structural composite	(i) Plywood (ii) Plastic matrix plastic fiber reinforced laminates (iii) Honeycomb core sand-wich panel	(i) Construction of differ-ent structure, House-hold use, etc. (ii)Modern snow ski (iii) Roof, floor and walls of building, aircraft components,

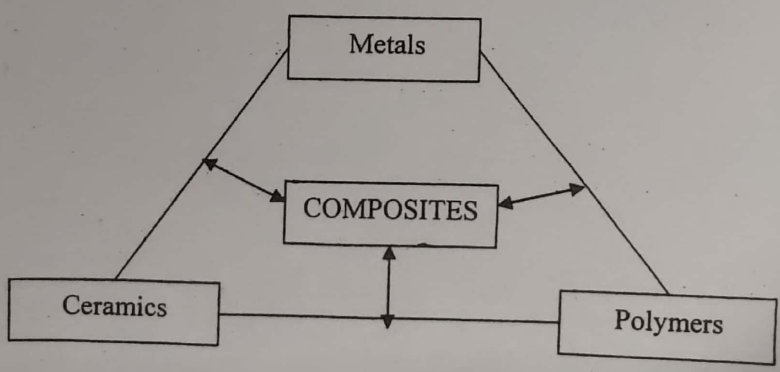
Modern composites examples

The most advanced examples are used on spacecraft in demanc environments. The most visible applications are paved roadways in the form of Port cement concrete, Mastic asphalt and asphalt concrete.

Engineered composite materials must be formed to shape. This invo strategically placing the reinforcements while manipulating the matrix properti achieve a melding event at or near the beginning of the component life cycl variety of methods are used according to the end item design requirements. Tl fabrication methods are commonly named moulding or casting processes appropriate, and both have numerous variations. The principle factors impacting methodology are the natures of the chosen matrix and reinforcement materials. Anc important factor is the gross quantity of material to be produced. Large quantities be used to justify high capital expenditures for rapid and automated manufactu technology. Small production quantities are accommodated with lower cap expenditures but higher labour costs at a correspondingly slower rate.

10.2 Composition of Composites

Generally, a composite material is composed of reinforcement (fibers, partic flakes, and/or fillers) embedded in a matrix (polymers, metals, or ceramics). matrix holds the reinforcement to form the desired shape while the reinforcem improves the overall mechanical properties of the matrix. A synergism produ material properties unavailable from naturally occurring materials.



Due to the wide variety of matrix and reinforcement materials available, the design potential is incredible. When designed properly, the new combined material exhibits better strength than would each individual material. The strength of the composites depends on properties of constituents, their relative amount and the geometry of the particles and orientation of the particles.

Choosing materials for the matrix

The matrix phase is the main constituent of the composite surrounding the other phase and gives the composite its bulk form. The matrix may be a metal, ceramic, polymer, carbon or particulate. Matrix being the backbone of the composite, it acts as the load bearing part which receive the applied load, transmit and distribute in itself and in the dispersed phase. So it should be ductile and should have low value of elastic modulus. Again, it should form strong bonding with dispersed phase.

For the matrix, many modern composites use thermosetting or thermo softening plastics (also called resins). (The use of plastics in the matrix explains the name 'reinforced plastics' commonly given to composites). The plastics are polymers that hold the reinforcement together and help to determine the physical properties of the end product.

Thermosetting plastics are liquid when prepared but harden and become rigid (ie, they cure) when they are heated. The setting process is irreversible, so that these materials do not become soft under high temperatures. These plastics also resist wear and attack by chemicals making them very durable, even when exposed to extreme environments.

Thermo softening plastics, as the name implies, are hard at low temperatures but soften when they are heated. Although they are less commonly used than thermosetting plastics they do have some advantages, such as greater fracture toughness, long shelf life of the raw material, capacity for recycling and a cleaner, safer workplace because organic solvents are not needed for the hardening process.

Ceramics, carbon and metals are used as the matrix for some highly specialized purposes. For example, ceramics are used when the material is going to be exposed to high temperatures (eg, heat exchangers) and carbon is used for products that are exposed to friction and wear (eg, bearings and gears).

Choosing materials for the reinforcement

It is the structural constituent of the composite which determines its internal structure and remain as dispersed phase in the main body. The dispersed phase may be taken in different physical states like particulates, fibers, whiskers and flakes.

Particulate- These are powder or fine granules of varying size and shape. They are hard and strong and may be made from metals, ceramics, carbon and polymer. A particulate composite is made by adding particles to a liquid matrix material, which later solidifies or may be pressed together by powder process. In such composite the matrix as well as the particulate shares the load-bearing function. The effective strength depends on the volume fraction of particulates, inter particle spacing and bonding between the matrix and the particles. As the volume fraction of particulate increases the mechanical properties improves reaching an optimum value and then begin to fal when it is very large as compared to the matrix. Examples of this type of composite are concrete, cermets, tungsten thoria etc.

Fibers- It is any elongated material made from carbon, glass, aramid having high length to diameter ratio. Fibers of circular cross section are used mostly in production composite.

Although glass fibres are by far the most common reinforcement, many advanced composites now use fine fibers of pure carbon. Carbon fibres are much stronger than glass fibres, but are also more expensive to produce. Carbon fibre composites are light as well as strong.

Polymers are not only used for the matrix, they also make a good reinforcement material in composites. For example, Kevlar is a polymer fibre that is immensely strong and adds toughness to a composite. It is used as the reinforcement in composite products that require lightweight and reliable construction.

Alumina fibres   Carbon fibres   Kelvar fibres

x 50, 100 micro meters   x 500, 10 micro meters

Fig. 10.2

Whiskers- They are oxides, nitrates, carbides, halide of various metals like Fe, Cu, Pb, Mn, Zn, Cd, Sn, Cr, and graphite etc. of several mm in length and several micron in diameter or thickness. They possess high strength and elastic modulus. Irregularities decrease their strength but perfect whiskers possess higher strength.

Flakes   Whiskers

Fig. 10.3

Flakes- Thin flakes primarily have two-dimensional geometry; they impart equal strength in all directions in their plane as compared to fiber that are unidirectional reinforcements. Flakes can be packed more efficiently than fibers or spherical particles. For example, mica flakes are used in electrical and heat insulating applications.

Examples of composite materials:

- Fiber Reinforced Polymers or FRPs:
  - Classified by type of fiber:
    - Wood (cellulose fibers in a lignin and hemicellulose matrix)
    - Carbon-fiber reinforced plastic or CFRP
    - Glass-fiber reinforced plastic or GFRP
  - Classified by matrix:
    - Thermoplastic Composites
    - Thermoset Composites
- Reinforced carbon-carbon (carbon fiber in a graphite matrix)

- Metal matrix composites or MMC:
    - White cast iron
    - Hard metal (carbide in metal matrix)
    - Metal-intermetallic laminate
- Ceramic matrix composites:
    - Bone (hydroxyapatite reinforced with collagen fibers)
    - Cermet (ceramic and metal)
    - Concrete
- Organic matrix/ceramic aggregate composites
    - Asphalt concrete
    - Mastic asphalt
    - Mastic roller hybrid
    - Dental composite
    - Syntactic foam
    - Mother of Pearl