“23ME709-COMPOSITE MATERIALS”

Course contents

Mrs.SWESHAREEFA MAHAKUL

Assistant Professor

In the department of

Mechanical Engineering

NARASIMHA REDDY ENGINEERING COLLEGE
(Affiliated to JNTU, HYDERABAD)
MAISAMMGUDA(V),DHULAPALLY(P),MEDCHAL(M)
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UNIT-I

INTRODUCTION

Introduction to Composite Materials

A composite material is a material that consists of one or more discontinuous components (particles/fibres/reinforcement) that are placed in a continuous medium (matrix).In a fibre composite the matrix binds together the fibres, transfers loads between the fibres and protects them from the environment and external damage.

Composite materials, or shortened to composites, are microscopic or macroscopic combinations of two or more distinct engineered materials (those with different physical and/or chemical properties) with a recognizable interface between them in the finished product. For structural applications, the definition can be restricted to include those materials that consist of a reinforcing phase such as fibers or particles supported by a binder or matrix phase. Wood composites are commonly seen examples of composite materials.

Other features of composites include the following: (1) The distribution of materials in the composite is controlled by mechanical means. (2) The term composite is usually reserved for materials in which distinct phases are separated on a scale larger than atomic,and in which the composite’s mechanical properties are significantly altered from those of the constituent components. (3) The composite can be regarded as a combination of two or more materials that are used in combination to rectify a weakness in one material by a strength in another. (4) A recently developed concept of composites is that the composite should not only be a combination of two materials, but the combination should have its own distinctive properties. In terms of strength, heat resistance, or some other desired characteristic, the composite must be better than either component alone.

Composites were developed because no single, homogeneous structural material could be found that had all of the desired characteristics for a given application. Fiber-reinforced composites were first developed to replace aluminum alloys, which provide high strength and fairly high stiffness at low weight but are subject to corrosion and fatigue.

An example of a composite material is a glass-reinforced plastic fishing rod in which glass fibers are placed in an epoxy matrix. Fine individual glass fibers are characterized by their high tensile stiffnesses and very high tensile strengths, but because of theirsmall diameters, have very small bending stiffnesses. If the rod were made only of epoxy plastic, it would have good bending stiffness, but poor tensile properties. When the fibers are placed in the epoxy plastic, however, the resultant structure has high tensile stiffness, high tensile strength, and high bending stiffness.

The discontinuous filler phase in a composite is usually stiffer or stronger than the binder phase. There must be a substantial volume fraction of the reinforcing phase (about10%) present to provide reinforcement. Examples do exist, however, of composites where the discontinuous phase is more compliant and ductile than the matrix.

Natural composites include wood and bone. Wood is a composite of cellulose and lignin. Cellulose fibers are strong in tension and are flexible. Lignin cements these fibers together to make them stiff. Bone is a composite of strong but soft collagen (a protein) and hard but brittle apatite (a mineral).

Particulate composites

Various geometrical shapes (cubes, spheres, flakes, etc.)
Various materials (rubber, metal, plastics, etc.)
Have generally low strength.
Will not be treated further in this course.

Particle reinforced metal matrix composites are now being produced commerically, and in this paper the current status of these materials is reviewed. The different types of reinforcement being used, together with the alternative processing methods, are discussed. Depending on the initial processing method, different factors have to be taken into consideration to produce a high quality billet. With powder metallurgy processing, the composition of the matrix and the type of reinforcement are independent of one another. However, in molten metal processing they are intimately linked in terms of the different reactivities which occur between reinforcement and matrix in the molten state. The factors controlling the distribution of reinforcement are also dependent on the initial processing method. Secondary fabrication methods, such as extrusion and rolling, are essential in processing composites produced by powder metallurgy, since they are required to consolidate the composite fully. Other methods, such as spray casting, molten metal infiltration, and molten metal mixing give an essentially fully consolidated product directly, but extrusion, etc., can improve the properties by modifying the reinforcement distribution. The mechanical properties obtained in metal matrix composites are dependent on a wide range of factors, and the present understanding, and areas requiring further study, are discussed. The successful commercial production of metal matrix composites will finally depend on their cost effectiveness for different applications. This requires optimum methods of processing, machining, and recycling, and the routes being developed to achieve this are considered.

Fibre composites
Discontinuous or Continuous

Classification of Composites:

• Matrices:
Organic Matrix Composites (OMCs)
Polymer Matrix Composites (PMCs)
carbon-carbon composites
Metal Matrix Composites (MMCs)
Ceramic Matrix Composites (CMCs)
• Reinforcements:
Fibres reinforced composites
Laminar composites
Particulate composites

Carbon Fiber is a polymer and is sometimes known as graphite fiber. It is a very strong material that is also very lightweight. Carbon fiber is five-times stronger than steel and twice as stiff. Though carbon fiber is stronger and stiffer than steel, it is lighter than steel; making it the ideal manufacturing material for many parts. These are just a few reasons why carbon fiber is favored by engineers and designers for manufacturing.

Properties of Composite Materials:

1 **High Strength to Weight Ratio:** Fibre composites are extremely strong for their weight. By refining the laminate many characteristics can be enhanced. A common laminate of say 3mm Chopped strand mat, is quite flexible compared to say a 3 mm ply. However it will bend a long way more than the ply before yielding. Stiffness should not be confused with Strength. A carbon fibre laminate on the other hand, will have a stiffness of many times that of mild steel of the same thickness, increased ultimate strength, yet only be less than 1/4 of it's weight.

2 **Lightweight:** A standard Fibreglass laminate has a specific gravity in the region of 1.5, compared to Alloy of 2.7 or steel of 7.8. When you then start looking at Carbon laminates, strengths can be many times that of steel, but only a fraction of the weight. A DVD case lid was produced using carbon fibre to reduce the case's overall weight so that it could be carried as cabin baggage whilst traveling, and for improved security. It was used by support crew for the All Blacks during their 1999 Rugby World Cup campaign.

3 **Fire Resistance:** The ability for composites to withstand fire has been steadily improving over the years. There is two types of systems to be considered:
Fire Retardant - Are self extinguishing laminates, usually made with chlorinated resins and additives such as Antimony trioxide. These release CO2 when burning so when the flame source is removed, the self extinguish.
Fire Resistant - More difficult and made with the likes of Phenolic Resins. These are difficult to use, are cured with formaldehyde, and require a hi degree of post curing to achieve true fire resistance.
Other materials are also becoming more readily available to be used as in tumescent layers, which expand and blanket the surface, preventing spread of flame. There is a paint on coating usually applied to the back of the product laminate, plus a thin fibre film to go under the Gelcoat giving the outer surface a blanketing coat as well.
Fibreglass Developments Ltd produces a Fire Door as part of our **SteridorTM** range. Use of special Phenolic resin has allowed us to create the *only* fully tested Composite door in Australasia. Fire rated by BRANZ to 4 hours, this door is also approved by MAF as meeting all their Hygiene requirements.

4 **Electrical Properties:** Fibreglass Developments Ltd produced the Insulator Support straps for the Tranz Rail main trunk electrification. The straps, although only 4mm thick, meet the required loads of 22kN, as well as easily meeting insulation requirements.

5 **Chemical & Weathering Resistance:** Composite products have good weathering properties and resist the attack of a wide range of chemicals. This depends almost entirely on the resin used in manufacture, but by careful selection resistance to all but the most extreme conditions can be achieved. Because of this, composites are used in the manufacture of chemical storage tanks, pipes, chimneys and ducts, boat hulls and vehicle bodies.
FDL manufactured architectural panels for the construction of the Auckland Marine Rescue Centre. Composite panels were chosen because of their ability to withstand salty sea side conditions without corrosion.

6 **Colour:** Almost any shade of any colour can be incorporated into the product during manufacture by pigmenting the gelcoat used. Costs are therefore reduced by no further finishing or painting. Soluble dyes can be used if a translucent product is desired.
We do not however, recommend dark colours. These produce excessive heat on the

surface which can lead to the surface deteriorating and showing print through, where the Resin matrix cures more and shrinks, bringing the fibres to the surface. In extreme cases delamination can occur.

7. **Translucency:** Polyester resins are widely used to manufacture translucent mouldings and sheets. Light transmission of up to 85% can be achieved.
8. **Design Flexibility:** Because of the versatility of composites, product design is only limited by your imagination.
9. **Low Thermal Conductivity:** Fibreglass Developments has been involved in the development and production of specialized meat containers which maintain prime cuts of chilled meat at the correct temperature for Export markets. They are manufactured using the RTM process, with special reinforcing and foam inserts.
10. **Manufacturing Economy:** Fibreglass Developments produces several models of fuel pump covers for Fuel quip. Fibreglass is an ideal material for producing items of this type for many reasons, including being very economical. Because of its versatile properties, fibreglass can be used in many varied applications.

Advantages:

• Lower density (20 to 40%)
• Higher directional mechanical properties (specific tensile strength (ratio of material strength to density) 4 times greater than that of steel and aluminium.
• Higher Fatigue endurance .
• Higher toughness than ceramics and glasses.
• Versatility and tailoring by design.
• Easy to machine.
• Can combine other properties (damping, corrosion).
• Cost.

Applications:

Mulch: In nature we see plants and trees drop leaves that accumulate at their bases. Every year, a new layer is added while the old layers start to decompose. This is leaf mold, and it is a form of compost. What nature is doing is providing a protective layer over the roots of plants. This layer of vegetative material protects the bare soil during the summer months by reducing soil temperature, suppressing weed growth and reducing soil moisture loss. Our compost can do the same thing in our gardens and landscapes.To prepare any area for mulching, first clear away grass or weeds that might grow up through the mulch. Make sure to remove the roots of tough perennial weeds such as ground ivy. When using compost as a mulch in flower beds, vegetable gardens, landscape beds, or lawns, screen the finished compost. A simple screen can be made using ½-inch mesh hardware cloth and attaching it to a wooden frame. Place the screen over a wheel barrow or other container and sift the compost into it. The large pieces left behind can go into your next compost pile as an activator, introducing the necessary microorganisms. Cover the garden or bed area with screened compost to a depth of one to two inches. If you apply compost on a lawn, be sure it is finely ground or sifted. You have less of a chance of smothering the lawn. You may want to use ¼-inch mesh hardware cloth. One way to incorporate the compost is to aerate the sod, then apply a 1/8-inch to ¼-inch covering of fine compost. Use a rake to distribute the compost into the crevices. When mulching around trees and shrubs, screening may not be necessary. This is really a matter of aesthetic desire on your part.

Soil Amendment: We have already talked about how compost helps soil, especially sandy and clay soils. When starting a new garden soil amending is recommended before you plant. It is so much easier to add compost now than it is after the garden is planted. Cover the garden area with 3 to 4 inches of compost and till it into the upper six inches of the soil. If your garden is already established and you want to incorporate compost deeply into the soil, your options are limited.

With perennials, every time you add a new plant to the garden or divide an existing one, add compost. With annuals, you can add compost every spring. Loosen up the entire area where annuals will be planted and work in compost. Around trees and shrubs add at planting time, mixing no more than 25 percent of soil volume. Some references say not to use any at all for fear that the roots will remain in the planting hole area and not grow out into the surrounding soil. Keeping the compost level at one-quarter of the total soil volume will not lead to this problem. If you're concerned, use the compost as a mulch only.

Around existing trees it may be difficult to incorporate into the upper six inches of the soil. You can add compost by injecting nutrients the way professional arborists do. Drill 1-to 2-inch diameter holes 12 inches deep in the soil throughout the tree canopy and beyond at 18-inch spacing. Fill the bottom of each hole with recommended rates of dry fertilizer and then top off the holes with compost. For shrubs, the holes only need to be drilled 8 to 10 inches deep. This treatment should supply nutrients for two to three years.

Using Compost in Potting Mixes:

You can also blend fine-textured compost in potting mixtures. However, make sure the compost does not make up more than one quarter to one half of the potting mixture's volume. Plants growing in containers are entirely reliant on the water and nutrients provided in the potting mix. Compost is excellent for container growing mixes, because it stores moisture effectively and provides a variety of nutrients not typically supplied in commercial fertilizers or soil-free potting mixes. You still need to fertilize containers on a regular basis to provide the high volume of nutrients they need. Finely sifted compost can also be used in seed starting mixtures.

Compost Tea:

An old fashioned way of providing liquid fertilizer for plants is to brew compost tea. Similar to manure tea, compost tea gives your plants a good dose of nutrients. Compost tea works especially well for providing nutrients to new transplants and young seedlings. To make compost tea fill a burlap sack or an old pillow case with finished compost and secure the open end. Place in a tub, barrel, or watering can filled with water. Agitate for a few minutes and then let it steep for a few days. Water will leach out nutrients from the compost and the mixture will take on the color of tea. Spray or pour compost tea on and around plants. You can use the bag of compost for several batches. Afterwards, simply empty the bag's contents onto the garden.