Introduction to Composite Materials

LECTURE : 4: CHAPTER ONE
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1.4 Recycling Fiber-Reinforced Composites

What types of processes are used for recycling of composites?

The two main processes are called chemical and mechanical processes.

Why is recycling of composites complex?

This is because of the many variables in material types — thermoset vs. thermoplastics, long vs. short fibers, glass vs. carbon, etc.

What are the various steps in mechanical recycling of short fiber-reinforced composites?

These are shredding, separation, washing, grinding, drying, and extrusion.

Why is chemical recycling not as popular as mechanical recycling?

Chemical processing is very costly. Processes such as pyrolysis (decomposing materials in an oxygen-free atmosphere) produce many gases, and hydrogenation gives high filler content. However, General Motors has adapted pyrolysis to recycle composite automobile parts. Gases and oils are recovered, and the residues are used as fillers in concrete and roof shingles. One other problem is the chlorine content. The scrap needs to be dehalogenated after separation, especially if carbon fibers were used as reinforcement. Glass fibers in recycled composites also pose the problem of low compressive strength of the new material.

What can one do if the different types of composites cannot be separated?

Incineration or use as fuel may be the only solution because metals, thermosets, and thermoplastics may be mixed, and they may be soiled with toxic materials. The fuel value* of polymer matrix composites is around 5000 BTU/lb (11,622 kJ/kg). This is about half the value for coal.

Which chemical process; incineration or use as fuel shows the most promise?

Incineration offers the most promise.

Its advantages include minimal cost, high-volume reduction, and no residual material. It is also feasible for low scrap volume.

1.4 Mechanics Terminology

How is a composite structure analyzed mechanically?

A composite material consists of two or more constituents; thus, the analysis and design of such materials is different from that for conventional materials such as metals. The approach to analyze the mechanical behavior of composite structures is as follows (**Figure 1.35**).

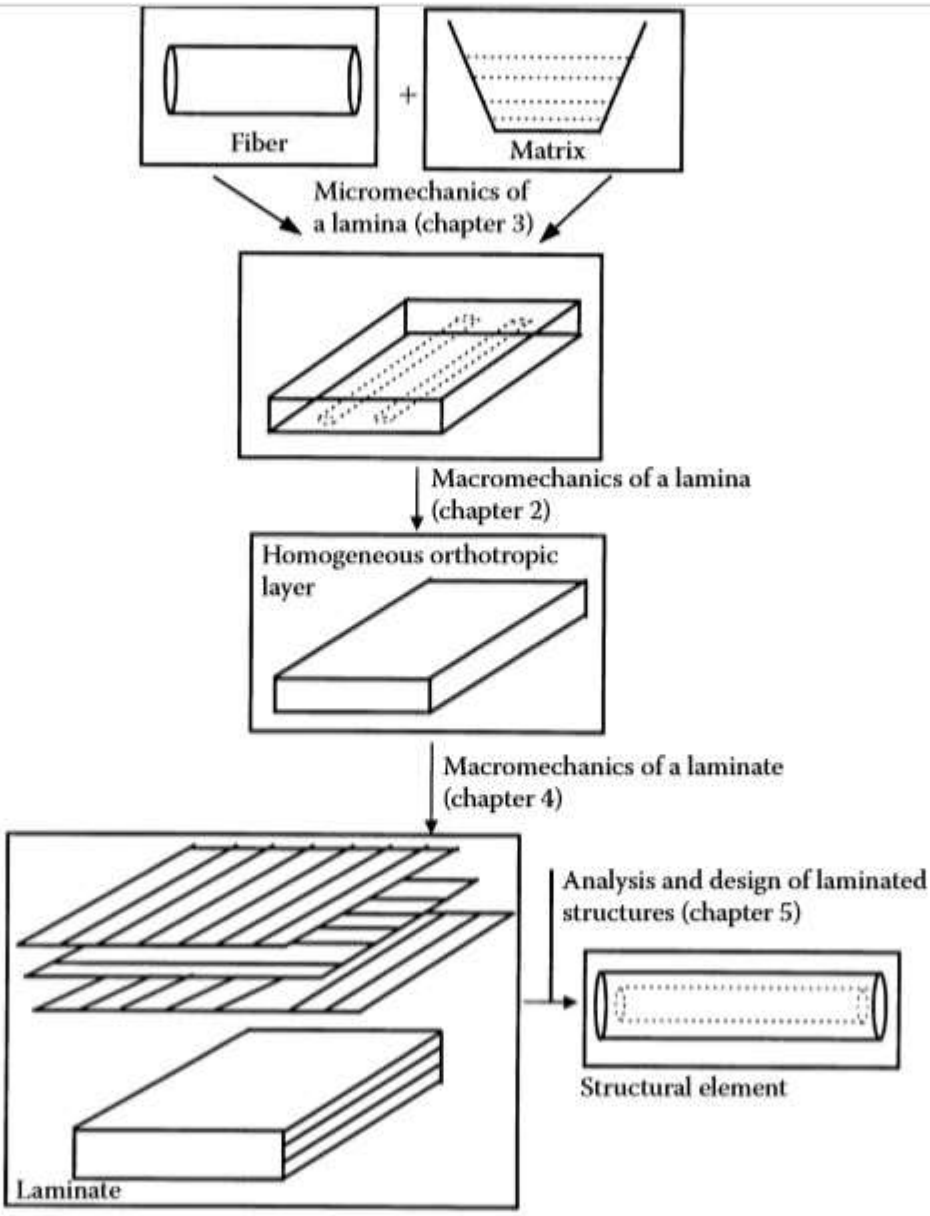

FIGURE 1.35
Schematic of analysis of laminated composites.

1. Find the average properties of a composite ply from the individual properties of the constituents. Properties include stiffness, strength, thermal, and moisture expansion coefficients. Note that average properties are derived by considering the ply to be homogeneous. At this level, one can optimize for the stiffness and strength requirements of a lamina. This is called the micromechanics of a lamina.
2. Develop the stress–strain relationships for a unidirectional/bidirectional lamina. Loads may be applied along the principal directions of symmetry of the lamina or off-axis. Also, one develops relationships for stiffness, thermal and moisture

expansion coefficients, and strengths of angle plies. Failure theories of a lamina are based on stresses in the lamina and strength properties of a lamina. This is called the macromechanics of a lamina.

A structure made of composite materials is generally a laminate structure made of various laminas stacked on each other. Knowing the macromechanics of a single lamina, one develops the macromechanics of a laminate. Stiffness, strengths, and thermal and moisture expansion coefficients can be found for the whole laminate. Laminate failure is based on stresses and application of failure theories to each ply. This knowledge of analysis of composites can then eventually form the basis for the mechanical design of structures made of composites. Several terms are defined to develop the fundamentals of the mechanical behavior of composites. These include the following.

What is an isotropic body? An isotropic material has properties that are the same in all directions. For example, the Young's modulus of steel is the same in all directions.

What is a homogeneous body? A homogeneous body has properties that are the same at all points in the body. A steel rod is an example of a homogeneous body. However, if one heats this rod at one end, the temperature at various points on the rod would be different. Because Young's modulus of steel varies with temperature, one no longer has a homogeneous body. The body is still isotropic because the properties at a particular point are still identical in all directions.

Are composite materials isotropic and/or homogeneous? Most composite materials are neither isotropic nor homogeneous. For example, consider epoxy reinforced with long glass fibers. If one chooses a location on the glass fiber, the properties are different from a location on the epoxy matrix. This makes the composite material nonhomogeneous (not homogeneous). Also, the stiffness in the direction parallel to the fibers is higher than in the direction perpendicular to the fibers and thus the properties are not independent of the direction. This makes the composite material anisotropic (not isotropic).

What is an anisotropic material?

At a point in an anisotropic material, material properties are different in all directions.

What is a nonhomogeneous body?

A nonhomogeneous or inhomogeneous body has material properties that are a function of the position on the body.

What is a lamina?

A lamina (also called a ply or layer) is a single flat layer of unidirectional fibers or woven fibers arranged in a matrix.

What is a laminate?

A laminate is a stack of plies of composites. Each layer can be laid at various orientations and can be made up of different material systems.

What is a hybrid laminate?

Hybrid composites contain more than one fiber or one matrix system in a laminate. The main four types of hybrid laminates follow.

- Interply hybrid laminates contain plies made of two or more different composite systems. Examples include car bumpers made of glass/ epoxy layers to provide torsional rigidity and graphite/epoxy to give stiffness. The combinations also lower the cost of the bumper.
- Intraply hybrid composites consist of two or more different fibers used in the same ply. Examples include golf clubs that use graphite and aramid fibers. Graphite fibers provide the torsional rigidity and the aramid fibers provide tensile strength and toughness.
- An interply–intraply hybrid consists of plies that have two or more different fibers in the same ply and distinct composite systems in more than one ply.

• Resin hybrid laminates combine two or more resins instead of combining two or more fibers in a laminate. Generally, one resin is flexible and the other one is rigid. Tests have proven that these resin hybrid laminates can increase shear and work of fracture properties by more than 50% over those of all-flexible or all-rigid resins.