Module 1: Introduction to Composites

Lecture 5: Terminologies

The Lecture Contains:

Introduction

In this lecture we are going to discuss some of the terms and their definitions that are used in the composites. These terms will be frequently used in our course. We will conclude this lecture with advantages and disadvantages of the composite materials.

Terminologies Used in Fibrous Composites

The following are the useful terminologies used in the composite related studies.

1. ***Filament*:** individual element
2. ***Strand:*** Bundles of 204 filaments or multiple of these.
3. ***Roving*:** Combination of strands to form thicker parallel bundles.
4. ***Yarns*:** strands are twisted to form yarns.
5. ***Aspect ratio:*** The ratio of length to diameter of a fiber.
6. ***Bi-component fibers:*** A fiber made by spinning two compositions concurrently in each capillary of the spinneret.
7. ***Blend:*** A mix of natural staple fiber such as cotton or wool and synthetic staple fibers such as nylon, polyester. Blends are made to take advantages of the natural and synthetic fibers.
8. ***Braiding:*** Two or more yarns are intertwined to form an elongated structure. The long direction is called the bias direction or machine direction.
9. ***Carding:*** Process of making fibers parallel by using rollers covered with needles.
10. ***Chopped strands:*** Fibers are chopped to various lengths, 3 to 50 mm, for mixing with resins.
11. ***Continuous fibers:*** Continuous strands of fibers, generally, available as wound fiber spools.
12. ***Cord:*** A relatively thick fibrous product made by twisting together two or more plies of yarn.
13. ***Covering power:*** The ability of fiber to occupy space. Noncircular fibers have greater covering power then circular fibers.
14. ***Crimp:*** Waviness along the fiber length. Some natural fibers e.g. wool, have a natural crimp. In synthetic polymeric fibers crimp can be introduced by passing the filament between rollers having teeth. Crimp can also be introduced by chemical means. This is done by controlling the coagulation of the filament to produce an asymmetrical cross-section.
15. ***Denier:*** A unit of linear density. It is the weight in grams of 9000m long yarn. This unit is commonly used in the US textile industry.
16. ***Fabric:*** A kind of planar fibrous assembly. It allows the high degree of anisotropy characteristic of yarn to be minimized, although not completely eliminated.
17. ***Felt:*** Homogeneous fibrous structure made by interlocking fibers via application of heat, moisture and pressure.
18. ***Filament:*** Continuous fiber, i.e. fiber with aspect ratio approaching infinity.
19. ***Fill:*** see Weft.
20. ***Handle:*** Also known as softness of handle. It is a function of denier (or tex), compliance, cross-section, crimp, moisture absorption, and surface roughness of the fiber.
21. ***Knitted fabric:*** One set of yarn is looped and interlocking to form a planar structure.
22. ***Knitting:*** This involves drawing loops of yarns over previous loops, also called interlooping.
23. ***Mat:*** Randomly dispersed chopped fibers or continuous fiber strands, held together with a binder. The binder can be resin compatible, if the mat is to be used to make a polymeric composite.
24. ***Microfibers:*** Also known as microdenier fibers. These are fibers having less than 1denier per

filament (or less than 0.11 tex per filament). Fabrics made of such microfibers have superior silk-like handle and dense construction. They find applications in stretch fabrics, lingerie, rain wear, etc.

25. ***Monofilament:*** A large diameter continuous fiber, generally, with a diameter greater than 100 μm.
26. ***Nonwovens:*** Randomly arranged fibers without making fiber yarns. Nonwovens can be formed by spunbonding, resinbonding, or needle punching. A planar sheet-like fabric is produced from fibers without going through the yarns spinning step. Chemical bonding and/or mechanical interlocking is achieved. Fibers (continuous or staple) are dispersed in a fluid (i.e. a liquid or air) and laid in a sheet-like planar form on a support and then chemically bonded or mechanically interlocked. Paper is perhaps the best example of a wet laid nonwoven fabric where we generally use wood or cellulosic fibers. In spunbonded nonwovens, continuous fibers are extruded and collected in random planar network and bonded.
27. ***Particle:*** Extreme case of a fibrous form: it has a more or less equiaxial form, i.e. the aspect ratio is about 1.
28. ***Plaiting:*** see Braiding.
29. ***Rayon:*** Term use to designate any of the regenerated fibers made by the viscose, cuprammonium, or acetate processes. They are considered to be natural fibers because they are made from regenerated, natural cellulose.
30. ***Retting:*** A biological process of degrading pectin and lignin associated with vegetable fibers, loosening the stem and fibers, followed by their separation.
31. ***Ribbon:*** Fiber of rectangular cross-section with width to thickness ratio greater than 4.
32. ***Rope:*** Linear flexible structure with a minimum diameter of 4mm. it generally has three strands twisted together in a helix. The rope characteristics are defined by two parameters, unit mass and break length. Unit mass is simply g/m or *ktex*, while breaking length is the length of rope that will break under the force of its own weight when freely suspended. Thus, break length equals mass at break/unit mass.
33. ***Roving:*** A bundle of yarns or tows of continuous filaments (twisted or untwisted).
34. ***Spinneret:*** A vessel with numerous shaped holes at the bottom through which a material in molten state is forced out in the form of fine filaments or threads.
35. ***Spunbonding:*** Process of producing a bond between nonwoven fibers by heating the fibers to near their melting point.
36. ***Staple fiber:*** Fibers having short, discrete lengths (10-400 *mm* long) that can be spun into a yarn are called staple fibers. This spinning quality can be improved if the fiber is imparted a waviness or crimp. Staple fibers are excellent for providing bulkiness for filling, filtration, etc. Frequently, staple natural fibers, e.g. cotton or wool, are blended with staple synthetic fibers, e.g. nylon or polyester, to obtain the best of both types.
37. ***Tenacity:*** A measure of fiber strength that is commonly used in the textile industry. Commonly, the units are gram-force per denier, gram-force per tex, or Newton per tex. It is a specific strength unit, i.e. there is a factor of density involved. Thus, although the tensile strength of glass fiber is more than double that of nylon fiber, both glass and nylon fiber have a tenacity of about 6g/den. This is because the density of glass is about twice that of nylon.
38. ***Tex:*** A unit of linear density. It is the weight in grams of 1000m of yarn. Tex is commonly used in Europe.
39. ***Tow:*** Bundle of twisted or untwisted continuous fibers. A tow may contain tens or hundreds of thousands of individual filaments.
40. ***Twist:*** the angle of twist that individual filaments may have about the yarn axis. Most yarns have filaments twisted because it is easier to handle a twisted yarn then an untwisted one.
41. ***Wire:*** Metallic filament.
42. ***Warp:*** Lengthwise yarn in a woven fabric.
43. ***Weft:*** Transverse yarn in a woven fabric. Also called fill.

44. ***Whisker:*** Tiny, whisker-like fiber (a few mm long, a few μm in diameter) that is a single crystal and almost free of dislocations. Note that this term involves a material requirement. The small size and crystalline perfection make whiskers extremely strong, approaching the theoretical strength.
45. ***Woven fabric:*** Flat, drapeable sheet made by interlacing yarns or tows.
46. ***Woven roving:*** Heavy, drapeable fabric woven from continuous rovings.
47. ***Yarn:*** A generic term for a bundle of untwisted or twisted fibers (short or continuous). A yarn can be produced from staple fibers by yarn spinning. The yarn spinning process consists of some fiber alignment, followed by locking together by twisting. Continuous synthetic fibers are also used to make yarns. Continuous fibers are easy to align parallel to the yarn axis. Generally, the degree of twist is low, just enough to give some interfilament cohesion.

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What are the advantages of the composite materials?

The following are the advantages of composites:

1. ***Specific stiffness and specific strength:***

   The composite materials have high specific stiffness and strengths. Thus, these material offer better properties at lesser weight as compared to conventional materials. Due to this, one gets improved performance at reduced energy consumption.

2. ***Tailorable design***:

   A large set of design parameters are available to choose from. Thus, making the design procedure more versatile. The available design parameters are:

   1. Choice of materials (fiber/matrix), volume fraction of fiber and matrix, fabrication method, layer orientation, no. of layer/laminae in a given direction, thickness of individual layers, type of layers (fabric/unidirectional) stacking sequence.
   2. A component can be designed to have desired properties in specific directions.

3. ***Fatigue Life***:

   The composites can with stand more number of fatigue cycles than that of aluminum. The critical structural components in aircraft require high fatigue life. The use of composites in fabrication of such structural components is thus justified.

4. ***Dimensional Stability***:

   Strain due to temperature can change shape, size, increase friction, wear and thermal stresses. The dimensional stability is very important in application like space antenna. For composites, with proper design it is possible to achieve almost zero coefficient of thermal expansion.

5. ***Corrosion Resistance***:

   Polymer and ceramic matrix material used to make composites have high resistance to corrosion from moisture, chemicals.

6. ***Cost Effective Fabrication***:

   The components fabricated from composite are cost effective with automated methods like filament winding, pultrusion and tape laying. There is a lesser wastage of the raw materials as the product is fabricated to the final product size unlike in metals.

7. ***Conductivity***:

   The conductivity of the composites can be achieved to make it a insulator or a highly conducting material. For example, Glass/polyesters are non conducting materials. These materials can be used in space ladders, booms etc. where one needs higher dimensional stability, whereas copper matrix material gives a high thermal conductivity.

The list of advantages of composite is quite long. One can find more on advantages of composite in reference books and open literature.

What are the disadvantages of Composites?

1. Some fabrics are very hard on tooling.
2. Hidden defects are difficult to locate.
3. Inspection may require special tools and processes.
4. Filament-wound parts may not be repairable. Repairing may introduce new problems.
5. High cost of raw materials.
6. High initial cost of tooling, production set-up, etc.
7. Labour intensive.
8. Health and safety concerns.
9. Training of the labour is essential.
10. Environmental issues like disposal and waste management.
11. Reuse of the materials is difficult.
12. Storage of frozen pre-pregs demands for additional equipments and adds to the cost of production.
13. Extreme cleanliness required.
14. The composites, in general, are brittle in nature and hence easily damageable.
15. The matrix material is weak and hence the composite has low toughness.
16. The transverse properties of lamina or laminate are, in general, weak.
17. The analysis of the composites is difficult due to heterogeneity and orthotropy.

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