DEPARTMENT OF MECHANICAL ENGINEERING

COMPOSITE MATERIALS

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AE 1402 Composite Materials and structures

2 Marks Question and Answers

1 what is mean by composites?

It is fiber reinforced composite materials which consists of fibers of high strength and modulus embedded in or bonded to a matrix with distinct Interfaces between them.

2. TYPES OF GLASS FIBER.

- E-Glass – E stands for electrical
- S-Glass – S stands for high silica content
    - » High thermal expansion coefficient,
    - » High fatigue strength
- C-Glass – C stands for Corrosion
    - » Used in Chemical applications
    - » Storage tanks
- R-Glass – R stands for Rigid
    - » Structural applications
- D-Glass – D stands for Dielectric
    - » Low dielectric constants
- A-Glass – A Stands for appearance
    - » To improve surface appearance
    - » For ornamental works
- E-CR Glass – E-CR stands for Electrical and corrosion resistance
- AR Glass – AR stands for Alkali resistance

3. POLYMERIC MATRIX.

Epoxy, Polyester, Phenolic, Acrylic, Urethane, Polyamide

4. Properties of Composites.

- fatigue life
- temperature-dependent behavior
- thermal insulation
- thermal conductivity
- acoustical insulation
- strength
- stiffness
- corrosion resistance
- wear resistance
- attractiveness
- weight

5. Classification and characteristics of composites.

(1) *Fibrous composite materials* that consist of fibers in a matrix
(2) *Laminated composite materials* that consist of layers of various materials
(3) *Particulate composite materials* that are composed of particles in a matrix
(4) Combinations of some or all of the first three types

6.Particulate composite.

Particulate composite materials consist of particles of one or more materials suspended in a matrix of another material. The particles can be either metallic or nonmetallic as can the matrix.

7.Homogeneous material.

A *homogeneous* body has uniform properties throughout, i.e., the properties are independent of *position* in the body.

8. Isotropic material.

An *isotropic* body has material properties that are the same in every direction at a point in the body, i.e., the properties are independent of *orientation* at a point in the body.

9. Orthotropic material.

An *orthotropic* body has material properties that are different in three mutually perpendicular directions at a point in the body and, further, has three mutually perpendicular planes of material property symmetry. Thus, the properties depend on orientation at a point in the body.

10. Macro mechanics.

Macromechanics is the study of composite material behavior wherein the material is presumed *homogeneous* and the effects of the constituent materials are detected only as *averaged apparent macroscopic properties* of the composite material.

11. Micromechanics.

Micromechanics is the study of composite material behavior wherein the *interaction* of the constituent materials is examined on a *microscopic* scale to determine their effect on the properties of the composite material.

12. Materail utilization factor.

$$\text{Materials Utilization Factor} = \frac{\text{raw material weight}}{\text{final part weight}}$$

13. Monoclinic materials constants.

Monoclinic (13 independent constants) (for symmetry about z = 0)

$$\begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \gamma_{23} \\ \gamma_{31} \\ \gamma_{12} \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} & S_{13} & 0 & 0 & S_{16} \\ S_{12} & S_{22} & S_{23} & 0 & 0 & S_{26} \\ S_{13} & S_{23} & S_{33} & 0 & 0 & S_{36} \\ 0 & 0 & 0 & S_{44} & S_{45} & 0 \\ 0 & 0 & 0 & S_{45} & S_{55} & 0 \\ S_{16} & S_{26} & S_{36} & 0 & 0 & S_{66} \end{bmatrix} \begin{bmatrix} \sigma_1 \\ \sigma_2 \\ \sigma_3 \\ \tau_{23} \\ \tau_{31} \\ \tau_{12} \end{bmatrix}$$

14. Anisotropic material constants.

Anisotropic (21 independent constants):

$$\begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \gamma_{23} \\ \gamma_{31} \\ \gamma_{12} \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} & S_{15} & S_{16} \\ S_{12} & S_{22} & S_{23} & S_{24} & S_{25} & S_{26} \\ S_{13} & S_{23} & S_{33} & S_{34} & S_{35} & S_{36} \\ S_{14} & S_{24} & S_{34} & S_{44} & S_{45} & S_{46} \\ S_{15} & S_{25} & S_{35} & S_{45} & S_{55} & S_{56} \\ S_{16} & S_{26} & S_{36} & S_{46} & S_{56} & S_{66} \end{bmatrix} \begin{bmatrix} \sigma_1 \\ \sigma_2 \\ \sigma_3 \\ \tau_{23} \\ \tau_{31} \\ \tau_{12} \end{bmatrix}$$

15.Isotropic materail constants.

Isotropic (2 independent constants):

$$\begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \gamma_{23} \\ \gamma_{31} \\ \gamma_{12} \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} & S_{12} & 0 & 0 & 0 \\ S_{12} & S_{11} & S_{12} & 0 & 0 & 0 \\ S_{12} & S_{12} & S_{11} & 0 & 0 & 0 \\ 0 & 0 & 0 & 2(S_{11}-S_{12}) & 0 & 0 \\ 0 & 0 & 0 & 0 & 2(S_{11}-S_{12}) & 0 \\ 0 & 0 & 0 & 0 & 0 & 2(S_{11}-S_{12}) \end{bmatrix} \begin{bmatrix} \sigma_1 \\ \sigma_2 \\ \sigma_3 \\ \tau_{23} \\ \tau_{31} \\ \tau_{12} \end{bmatrix}$$

.

16. Orthotropic material constants.

Orthotropic (9 independent constants):

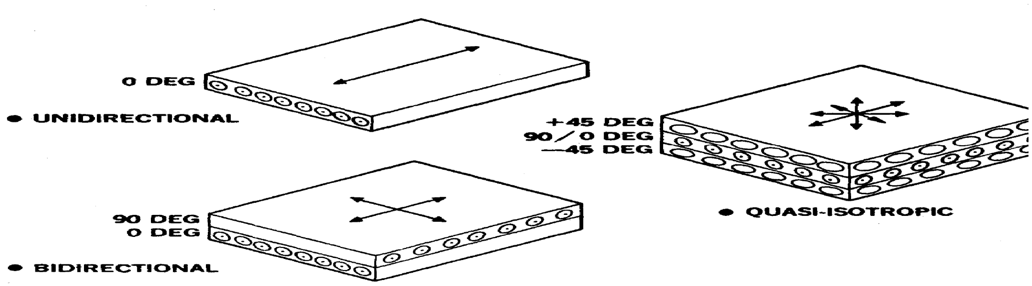
$$\begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \gamma_{23} \\ \gamma_{31} \\ \gamma_{12} \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} & S_{13} & 0 & 0 & 0 \\ S_{12} & S_{22} & S_{23} & 0 & 0 & 0 \\ S_{13} & S_{23} & S_{33} & 0 & 0 & 0 \\ 0 & 0 & 0 & S_{44} & 0 & 0 \\ 0 & 0 & 0 & 0 & S_{55} & 0 \\ 0 & 0 & 0 & 0 & 0 & S_{66} \end{bmatrix} \begin{bmatrix} \sigma_1 \\ \sigma_2 \\ \sigma_3 \\ \tau_{23} \\ \tau_{31} \\ \tau_{12} \end{bmatrix}$$

17. Transversely isotropic constants.

Transversely Isotropic (5 independent constants):

$$\begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \gamma_{23} \\ \gamma_{31} \\ \gamma_{12} \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} & S_{13} & 0 & 0 & 0 \\ S_{12} & S_{11} & S_{13} & 0 & 0 & 0 \\ S_{13} & S_{13} & S_{33} & 0 & 0 & 0 \\ 0 & 0 & 0 & S_{44} & 0 & 0 \\ 0 & 0 & 0 & 0 & S_{44} & 0 \\ 0 & 0 & 0 & 0 & 0 & 2(S_{11}-S_{12}) \end{bmatrix} \begin{bmatrix} \sigma_1 \\ \sigma_2 \\ \sigma_3 \\ \tau_{23} \\ \tau_{31} \\ \tau_{12} \end{bmatrix}$$

18. Unidirectional, bidirectional and quasi-isotropic fibers.



19. Anisotropic material

ANISOTROPIC Not isotropic; having mechanical and/or physical properties which vary with direction relative to the natural reference axes inherent in the material.

20.Laminate.

LAMINATE A product made by bonding together two or more layers or laminae of material or materials.

21.Matrix.

MATRIX The essentially homogeneous material in which the fibers or filaments of composite are imbedded.

21. pre-preg.

PREPREG, PREIMPREGNATED A combination of mat, fabric, nonwoven material, or roving with resin, usually advanced to the B-stage, ready for curing.

22. Resin

RESIN An organic material with indefinite and usually high molecular weight and no sharp melting point.

23.sandwich construction.

SANDWICH CONSTRUCTION A structural panel concept consisting in its simplest form of two relatively thin, parallel sheets of structural material bonded to and separated by a relatively thick, lightweight core.

24.vacuum bag molding.

VACUUM BAG MOLDING A process in which the layup is cured under pressure generated by drawing a vacuum in the space between the layup and a flexible sheet placed over it and sealed at the edges.

25.Features of composites.

The attractive features of advance composites are:

1. High strength-to-weight and high stiffness-to-weight ratio, as shown in Figures B10.1.0-3 and -4.
2. Ability to tailor the material to minimize weight and meet specific strength or stiffness requirements.
3. Can be fabricated to finished shape and thickness dimensions which require minimal trimming.
4. Excellent fatigue characteristics.
5. Adapatability to integrally stiffened design, eliminating multiple parts and fasteners.
6. Suitability for fabrication of large parts with complex shapes.

26.Adhesive.

ADHESIVE A substance capable of holding two materials together by surface attachment. The term is used specifically to designate structural adhesives, those which produce adhesion capable of transmitting significant structural loads.

27.Cross ply.

CROSS PLY Any filamentary lamina which is not uniaxial.

28.Lamina.

LAMINA A single ply or layer in a laminate made of a series of layers.

29.Porosity.

POROSITY A condition of trapped pockets of air, gas, or void within a solid material, usually expressed as a percentae of the total nonsolid volume to the total volume (solid + non-solid) of a unit quantity of material.

30. Shelf life.

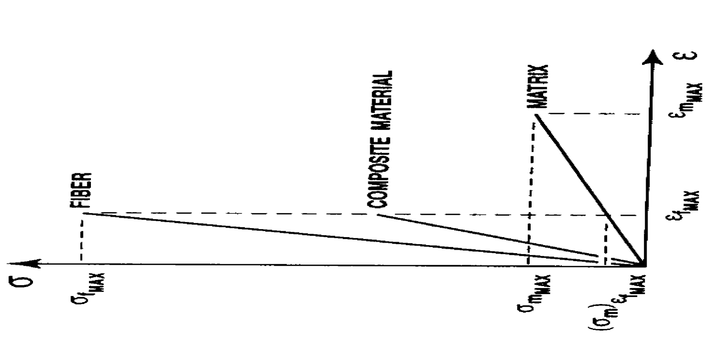
SHELF LIFE The length of time a material, substance, product, or reagent can be stored under specified environ-mental conditions and continue to meet all applicable specification requirements and/or remain suitable for its intended function.

31.Effect of Void content

32. Volume fraction of voids.

$$V_v = \frac{v_v}{v_c}$$

33. Graph between stress and strain.



34. Single layered continuous.

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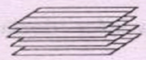
Single layered continuous

- Unidirectional 0° laminate



- Bidirectional

35. Major constituents of composite materials.

Fiber, Matrix, Fillers, Coupling agents, Coatings.

36. Fiber.

- Principal load carrying member.
- Main constituent and occupy largest volume fraction.
- The diameter of a fiber will be around 10μm.
- Commercially available fibers are of various types such as glass, carbon and kevlar 49.
- Fibers may be of Continuous or Discontinuos (chopped lengths) in lengths

37.Matrix

MATRIX

- Fibers are reinforced inside the matrix
- Keeps fiber in desired location and orientation.
- Acts as a load transfer medium
- Protects fiber from environmental damages due to elevated temperatures and humidity.
- Matrix material may be
  - a) Metal matrix
  - b) Polymeric matrix
  - c) Ceramic matrix

38.Coupling agents and coatings

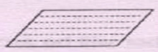
COUPLING AGENTS AND COATINGS

- These are applied on the fiber to improve their wetting with matrix
- To promote bonding between the fiber-matrix interface
- Protect the fiber from moisture and reactive fluids
- Coupling agent used with glass fiber is silanes (Organo functional silicon compound)

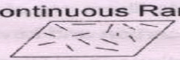
39.Single layered discontinuous.

Single layered Discontinuous

- Discontinuous Preferred



- Discontinuous Random

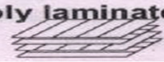


40. Multilayered composites.

Multilayered

- Angle ply laminate [θ/-θ/θ/-θ] θ ≠ 0° or 90°.

- Cross ply laminate [0°/90°/0°/90°].



41. Application of composites.

APPLICATION

- IN THE FIELD OF MILITARY AND COMMERCIAL AIR CRAFT [Weight reduction and Dynamic frequency tailoring]

Carbon fibers and Kevlar 49 used in wing, fuselage and empennage components

Fiber reinforced epoxies are used in rotor blades for military and commercial helicopters [Manufacturing flexibility]

Kevlar 49 or S-glass fibre reinforced epoxies used in filament wound motor cases

42.Fiber orientation.

- *Fiber orientation* in each layer as well as *stacking sequence* of the plies plays a major role in the strength and modulus of the composite laminates.

43. Carbon fiber.

CARBON FIBER

- **Advantages:**
  - High tensile strength to weight ratio
  - High tensile modulus to weight ratio (due to graphitic form of carbon)
  - Low cost
  - Low specific gravity
  - Low coefficient of thermal expansion (Dimensionally stable)
- **Dis advantages:**
  - Low impact resistance
  - High electrical conductivity

44.Boron fiber

BORON FIBER

- High tensile modulus
- Resistance to buckling
- High cost, therefore restricted application

Manufacturing:

- By chemical vapor deposition of boron on a heated substrate [Tungsten or carbon filament]
- Tungsten wire(0.0127 in dia) is pulled through a reaction chamber [$2 BCL_3 + 3 H_2 = 2B + 6 HCL$] in which boron is deposited on its surface at 1100-1300 °c
- Fiber diameter is controlled by pulling speed or deposition temperature.

45. Polyester properties.

Low cost, Translucent in nature, Operating temperature should be < 70 degree, Brittleness

High shrinkage rate

46. Phenolic properties.

Low cost, High mechanical strength, High void content

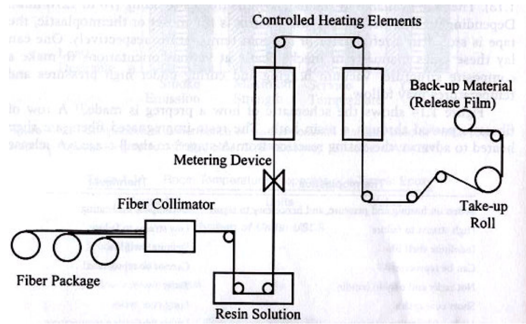
47. Epoxy properties.

High mechanical strength, Good adhesive nature, Low viscosity, Low volatility, Low shrinkage rate, High cost

48. Types of honeycomb.

1. paper honeycomb, Aluminium honeycomb, carbon fiber honeycomb, Armid paper honey comb, .Kevlar honeycomb, .Kevlar paper honeycomb.

49.Prepreg Manufacturing process



50. Failure in Sandwich structure.

Facing failure, Transverse shear failure, Local crushing failure

51. Roll – forming process.

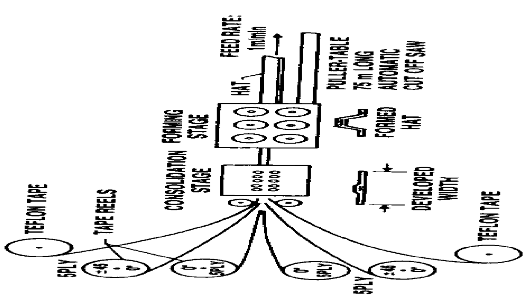


Figure 1-17 Roll-Forming Process

52. What are the factors consider while designing sandwich structures.

Sandwich is a composite structure.

Material used may be anisotropic

Core has sufficient shear

53. Different types core materials used in sandwich constructions.

Wood, Foam, PVC foam, Polystyrene foam, Polyurethane foams.

54. Advantages of sandwich construction.

Smooth exterior, Absence of potential leaks, High load carrying capacity,

It acts as a thermal and acoustic insulator.

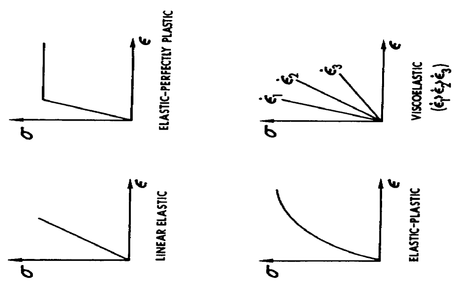
55. Face material used in sandwich constructions.

Unidirectional fiber, Graphite prepreg, Aluminium alloy, Stainless steel, Refractory metal.

56. Different ways in sandwich fabrication.

One step cure, Two step cure, Three step cure

57. Stress strain behaviors of various materials.



58. Important characteristics of Tsai-wu failure criteria.

59. Characteristics of composite laminate.

Specific gravity, Tensile strength, Compressive strength, Cost.

60. Flake composite.

It consist of flat reinforced of matrix typical flake material are glass, aluminum, and silver.

61. What are the drawbacks of polymer matrix composite?

PMC include low operating temperature high co-efficient of thermal and moisture expansion and low elastic properties in certain direction.

62. What are various types of polymers used in the advanced polymer composites?

These polymers include epoxy, phenolic, acrylic, urethane, and polyamide.

63. Apllication of composit in transportation.

MMCs are finding use now in automotive engines which are lighter than their metal counter parts also MMC are the material of choice for gas turbine engines for their high strength and low weight.

64. What is application of ceramic matrix?

CMS are finding increase application in high temperature areas where MMC and PMC can not be used this is not to say that CMC are not attractive otherwise especially if you look at their high strength and modules and low density.

65. What are carbon carbon composites?

It is used carbon fibers in a carbon matrix .It is used in very high temperature environments of up to 6000^{0}F and are 20 times stronger and 30% lighter than graphite fibers.

66. What are applications of carbon carbon composites?

Space shuttle nose cones, aircraft Srakes, mechanical fasteners.

67. What type's process used for recycling of composites?

Chemical and mechanical process.

68. Why recycling is complex.

There are many variables in material types: thermoset Vs thermoplastic, long Vs short fiber, Glass Vs carbon.

69. What are various steps in mechanical recycling of short fiber reinforced composites?

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

70. Which chemical process shows most promise?

Incineration offer most promise. It advantages include minimum cost, high volume reduction and no residual material. it is also feasible for low scrap volume.

71. What is Hybrid laminate?

Hybrid composite contain either more than one fiber are one matrix system in laminate.

72. What are types of hybrid laminate?

Interply hybrid laminate, intraply hybrid laminate, interply – intraply, resin hybrid laminate.

73. What is a non homogeneous body?

A non homogeneous body has material properties which are a function of the position on the body.

74. What are four elastic moduli of a unidirectional lamina?

Longitudinal young's modulus, Transverse young's modulus, Major Poisson ratio

In plane shear modulus

75. Failure of unidirectional ply under longitudinal tensile load.

Brittle fracture of fibers, Brittle fracture of fibers with pull out , Fiber pull out with fiber matrix debonding.

76. Total volume of composite.

$$vc = vf + vm + vv$$

77.Actual volume of composites

$$v_c = \frac{w_c}{\rho_{ce}}$$

78.theriotical volume of composite

$$v_f + v_m = \frac{w_c}{\rho_{ct}}$$

79. Weight of composites.

$$wc = wf + wm \quad \rho_c v_c = \rho_f v_f + \rho_m v_m$$

80.volume of composites.

$$vc = vf + vm$$

$$\frac{1}{\rho_c} = \frac{W_f}{\rho_f} + \frac{W_m}{\rho_m}$$

81.Classification of adhesives

Physical form - liquid adhesive, film adhesive

Chemical form – epoxy adhesive , polyamide

82. Advantages of bonded structures.

Improved fatigue, Crack arresting, Weight saving

83. Shelf life.

Shelf life of adhesive means the time from he date manufacture to the termination of life of adhesive due to its deterioration by ageing process.

84. what are adhesives.-Phenolic resin – vinyl phenplic, nitrile, epoxy phenolic.

Epoxy resin – epoxy polyamide.

85. What are adhesive bonded joints?- Lap joint, Butt joint , Angle joint, Corner joint

86. Continuous process.- Pultrusion, Braiding

87. Open mould process.

Spray layup, Hand layup, Filament winding, Sheet molding compound, Contact molding.

88. Close mould process.

Compression molding, Vacuum bag, Pressure bag , Autoclave ,Injection molding

Resin transfer

89. Advantages of open mould process.

Freedom to design, Easy to change design, Low mould and tooling cost,

Tailored properties possible

90. Disadvantages of open mould process.

Low to medium number of parts, Long cycles times per molding, Operator skill depended

91. Advantages of spray lay-up.

Widely used for many years, Low cost way of quickly depositing Fiber and resin,

Low cost tooling.

92. Plastic foams.

The expanded plastic foams made of PVC, polystyrene, phenolic resin, rubber

Are used as light weight cores.

93. Thermoplastics.

Thermoplastics don't undergo a chemical reaction on application of heat. Thermoplastics can be softened and they undergo large and rapid change in viscosity with variation in temperature.

94. Specific flexural rigidity.

It is the ratio between flexural rigidity and weight.

95. Disadvantages of filament winding.

Difficulty to winding complex shapes, Poor external finish, limited to convex shape component.

96. Theory of fiber strengthening.

$Ec = E_f V_f + E_m V_m$

97 Open mould process.

Spray layup, Hand layup, Filament winding, Sheet molding compound, Contact molding

98. Continuous process.

Pultrusion, Braiding

99. What are adhesive bonded joints?

Lap joint, Butt joint , Angle joint, Corner joint

100. What are types of hybrid laminate?

Interply hybrid laminate, intraply hybrid laminate, interply – intraply, resin hybrid laminate.

Unit1

1. What are the major constituents in composite materials?
   Reinforcing phase
   One in which it is embedded is called the matrix.
   Reinforcing phase - Fibres, particles or flakes.
   Matrix- Materials are generally continuous.

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

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

4. Define Hooke's law.
   Within elastic stress is proportional to strain. (e.g) Spring balance.
5. Write compliance and stiffness matrices for Hooke's law stress-strain relationships at a point in an x-y-z orthogonal system.

$$\begin{bmatrix} \varepsilon x \\ \varepsilon y \\ \varepsilon z \\ \gamma yz \\ \gamma zx \\ \gamma xy \end{bmatrix} = \begin{bmatrix} \frac{1}{E} & -\frac{\nu}{E} & -\frac{\nu}{E} & o & o & o \\ -\frac{\nu}{E} & \frac{1}{E} & -\frac{\nu}{E} & o & o & o \\ -\frac{\nu}{E} & -\frac{\nu}{E} & \frac{1}{E} & o & o & o \\ o & o & o & \frac{1}{G} & o & o \\ o & o & o & o & \frac{1}{G} & o \\ o & o & o & o & o & \frac{1}{G} \end{bmatrix} \begin{bmatrix} \sigma x \\ \sigma y \\ \sigma z \\ \tau yz \\ \tau zx \\ \tau xy \end{bmatrix}$$

6. What are advanced composites?
   Advanced composites are composite materials which are traditionally used in the aerospace industries. These composites have high performance reinforcements of a thin dia. in a matrix material such as epoxy and aiuminium.

7. List down the reinforcement materials and resins used in composite materials.
   <u>Reinforcement materials</u>
   Graphite, Glass, Aramid, Kevlar 49, Boron
   <u>Resins</u>
   Epoxy, aluminium, Polyamide, Nylon, Polyesters, Vinyl esters, Phenolics, Polymides, Polybenzimidazoles, Polyphenylquinoxaline.

8. Why are fiber reinforcements of a thin diameter?
   (i) As the fibers become smaller in diameter , it reduces the chances of an

inherent flaw in the material.
(ii) Fixed fiber volume in a given volume of composite, the area of the fiber-matrix interface is inversely proportional to the diameter of the fiber.
(iii) Ability to bend increases with a decrease in the fiber diameter and is measured as flexibility.

9. What are the aircraft structural components made of composite materials?
Elevator face sheets, Horizontal stabilizer, Wing spoilers, ailerons, rudders, elevators, fairings etc.,
Skin on the horizontal stabilizer box, Under wing fairings, fin, rudder and stabilizer skins, skins on vertical fin box, fin leading edge, wing skins, horizontal and vertical tail boxes ; wing and tail control surfaces etc., Wing skins and sub structure; forward fuselage; horizontal stabilizer flaps; ailerons.

10. Explain the difference between isotropic and anisotropic materials.
Anisotropic materials are the opposite of isotropic materials like steel and aluminium. Anisotropic materials have different properties in different directions. For example, the Young's modulus of a piece of wood is higher (different) in the direction of the grain than in the direction perpendicular to the grain. In comparison, a piece of steel has the same young's modulus in all directions.

11. What are the material constants of an orthotropic materials?
For an orthotropic material, the nine independent elastic constants are E11, E22, E33, G12, G13, G23, $\nu_{12,}$ $\nu_{13,}$ $\nu_{22.}$

Uni-directionally oriented fiber composites are a special class of orthotropic materials. If the fibers are in the 1-2 plane, elastic properties are equal in the 2-3 directions so that E22=E33, $\nu_{12}=\nu_{13}$ and $G_{12}=G_{13}$. Further more G23 can be expressed in terms of E22 and ν_{12}. Thus the number of independent elastic constants for a unidirectionally oriented fiber composite reduces to 5. Such composites are often called transversely isotropic.

12. What are the properties of matrices? Write down its usage.
Properties
Low viscosity.
High melting point.
Low curing temperature.
Usage:

To transfer stresses between the fibers.
To provide a barrier against an adverse environment.
To protect the surface of the fibers from mechanical abrasion.

13. Define (a) Orthotropic material (b) isotropic material and give the number of elastic constants in macro mechanics.
If a material has three mutually perpendicular planes of material symmetry it is called orthotropic material. Three mutually perpendicular planes of material symmetry also imply that there are three mutually perpendicular planes of material symmetry. Note there are nine independent elastic constants.

If all planes in an orthotropic body are identical, it is an isotropic material. This also implies that there are infinite principal directions. Note that there are two independent constants.

14. What is meant by orthogonally isotropic material? Give an example.
The Q_{16} qnd Q_{26} terms are non-zero when □ has any value other than 0º or 90º. This indicates the anisotropic behaviour of an orthotropic lamina when its fibers are not oriented along or perpendicular to the reference load direction. The terms Q16 and Q26 are that cause an orthotropic lamina to behave like an anisotropic lamina in a laminate, when □ is neither 0º nor 90º.(Better 30º and 60º).

15. Define composite materials.
A composite is a structural material which consists of combining two or more constituents. The constituents are combined at a macroscopic level and are not soluble in each other. One constituent is called the reinforcing phase and the one in which it is embedded is called the matrix.

16. What is an isotropic body?
A 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.

17. Write four applications of composite materials?
Air craft. Space, automotive, sporting goods and marine engineering.

18. Distinguish between long fibers and short fibers.
Long fibers: Easy to orient & process. Impact resistance, low shrinkage, improved surface finish and dimensional stability.
Short fibers : Low cost, Easy to work with matrix. Short fibers have few flaws and therefore have higher strength.

19. What is a particulate composite?
It consists of particles immersed in matrices such as alloys and ceramics. They are usually isotropic since the particles are added randomly.

20. What is an anisotropic material?
At a point in anisotropic material, material properties are different in all directions. The material which has 21 independent elastic constants at a point is called an anisotropic material.

Unit 2

1. What are the assumptions made in the strength of materials approach model?
(i)The bond between fibers and matrix is perfect.
(ii) The elastic moduli, diameters and space between fibers are uniform.
(iii)The fibers are continuous and parallel.
(iv)The fibers and matrix follow Hooke's law.(linearly elastic)
(v)The fibers possess uniform strength.
(vi)The composite is free of voids.

2. Find the in-plane shear modulus of a glass/epoxy lamina with a 70% fiber volume fraction. $G_f = 35.42$ GPa; $G_m = 1.308$ GPa.
$$\frac{1}{G_{12}} = \frac{0.7}{35.42} + \frac{0.3}{1.308}$$
$$G_{12} = 4.014 GPa$$

3. Define micro mechanics.
Micro mechanics is the study of composite material behaviour wherein the interaction of the constituent materials is examined on a microscopic scale to determine their effect on the properties of the composite material.

4. Find the transverse Young's modulus of a glass/epoxy lamina with a 70% fiber volume fraction. $E_f = 85$ GPa; $E_m = 3.4$GPa.
$$\frac{1}{E2} = \frac{Vf}{Ef} + \frac{Vm}{Em}$$
$$= \frac{0.7}{85} + \frac{0.3}{3.4}$$
E_2 = 10.37 GPa.

5. Distinguish between natural axis and arbitrary axis.
The axis parallel to the nominal axis, it is called natural axis or right hand co-ordinate system.
The axis is some inclining of plane is called arbitrary plane.

6. What is macro mechanics?
The macro mechanical analysis of a lamina is based on average properties and by considering the lamina to be homogeneous. Methods to find these average properties based on the individual mechanical properties of the fiber and the matrix.

7. Define material axes or local axes.
The axes in the 1-2 co-ordinate system are called the local axes or the material axes. The direction 1 is parallel to the fibers and the direction 2 is perpendicular to the fibers. Direction 1 is also called the longitudinal direction (L) and the direction 2 is called the transverse direction (T). The axes in the x-y co-ordinate system are called the global axes or the off axes.

8. What is density of composites?
The mass of composite (Wc) is the sum of the mass of the fibers (Wf) and the mass of the matrix (Wm) is
Wc= Wf + Wm
The density of the composite in terms of mass fraction
$$\frac{1}{\rho c} = \frac{Wf}{\rho f} + \frac{Wm}{\rho m}$$

9. What is elasticity approach?
Elasticity accounts for equilibrium of forces, compatibility and Hooke's law relationships in three dimensions, whereas the strength of materials approach may not satisfy compatibility and not account for Hooke's law in three dimensions.

10. What is major poisson's ratio?
The major poisson's ratio is defined as the negative of the ratio of the normal strain in the transverse direction to the normal strain in the longitudinal direction, when a normal load is applied in the longitudinal direction.

11. Write the general characteristics of composite materials.
Low specific gravity.
High strength weight ratio.
High modulus-weight ratio.

12. What is meant by "stiffness".
A measure of modulus
The relationship of load and deformation
The ratio between the applied stress and resulting strain.

13. Write short notes on: Resilience.
A property of a material, which is able to do work against restraining, forces during return from a deformed condition.

14. What are the assumptions made in micro mechanics?
Micro mechanics – The study of composite material behaviour wherein the interaction of the constituent materials is examined in detail as part of the definition of the behaviour of the heterogeneous composite material.
The two basic approaches to the micromechanics of composite materials are
   (i) Mechanics of materials
   (ii) Elasticity
The mechanics of materials (or strength of materials or resistance of materials) approach embodies the usual concept of vastly simplifying assumptions regarding the hypothesized behaviour of the mechanical system. The elasticity approach actually is at least three approaches (i) bounding principles (ii) exact solutions and (iii) approximate solutions. All approaches are characterized by more rigorous satisfaction of physical laws (equilibrium, deformation continuity and compatibility and stress-strain relations) than in mechanics of materials.

15. What is fiber reinforced plastic (FRP)?
A general term for a composite that is reinforced with cloth, mat, strands or any other fiber form.

16. Define the term: constituent.
In general, an element of a larger grouping. In advanced composites, the principal constituents are the fibers and the matrix.

17. 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. Since young's modulus of steel varies with temperature, we no longer have a homogeneous body.

18. What is a non homogeneous body?
A non-homogeneous or inhomogeneous body has material properties which are a function of the position on the body.

19. How local and global stresses are related?
The global and local stresses in an angle lamina are related to each other through the angle of the lamina, □

$$\begin{bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{bmatrix} = [T]^{-1} \begin{bmatrix} \sigma_1 \\ \sigma_2 \\ \sigma_{12} \end{bmatrix}$$

Where [T] is called the transformation matrix and is defined as

$$[T]^{-1} = \begin{bmatrix} c^2 & s^2 & -2sc \\ s^2 & c^2 & 2sc \\ sc & -sc & c^2 - s^2 \end{bmatrix}$$

20. What are the elements of the transformed reduced stiffness matrix ?

$$\bar{Q}_{11} = Q_{11}C^4 + Q_{22}S^4 + 2(Q_{12} + 2Q_{66})S^2C^2$$

$$\bar{Q}_{12} = (Q_{11} + Q_{22} - 4Q_{66})S^2C^2 + Q_{12}(C^4 + S^4)$$

$$\bar{Q}_{22} = Q_{11}S^4 + Q_{22}C^4 + 2(Q_{12} + 2Q_{66})S^2C^2$$

$$\bar{Q}_{16} = (Q_{11} - Q_{12} - 2Q_{66})C^3 S - (Q_{22} - Q_{12} - 2Q_{66})S^3 C$$

$$\bar{Q}_{26} = (Q_{11} - Q_{12} - 2Q_{66})C S^3 - (Q_{22} - Q_{12} - 2Q_{66})C^3 S$$

$$\bar{Q}_{66} = (Q_{11} + Q_{22} - 2Q_{12} - 2Q_{66})S^2 C^2 + Q_{66}(S^4 + C^4)$$

Unit 3

1. Distinguish between symmetric cross ply laminate and symmetric angle ply laminate.
   Symmetric cross ply laminates
   Odd no. of plies
   [0/90/0/90/0]
   Symmetric angle ply laminates
   + □ and – □ directions
   Odd no. of plies
   [-40/40/-40/40/-40]

2. Give an example of a laminate with zero coupling stiffness matrix,
   Symmetric laminates
   A laminate is called symmetric if the material, angle and thickness of plies are the same above and below the mid-plane. A example of symmetric laminates is [0/30/$\overline{60}$]s as shown below:
   /0/30/60/30/0/
   For symmetric laminates from the definition of [B] matrix, it can be proved [B]=0. Hence

$$\begin{bmatrix} N_x \\ N_y \\ N_z \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} & A_{16} \\ A_{12} & A_{22} & A_{26} \\ A_{16} & A_{26} & A_{66} \end{bmatrix} \begin{bmatrix} \varepsilon_x^{\circ} \\ \varepsilon_y^{\circ} \\ \varepsilon_z^{\circ} \end{bmatrix}$$

$$\begin{bmatrix} M_x \\ M_y \\ M_z \end{bmatrix} = \begin{bmatrix} D_{11} & D_{12} & D_{16} \\ D_{12} & D_{22} & D_{26} \\ D_{16} & D_{26} & D_{66} \end{bmatrix} \begin{bmatrix} \kappa_x \\ \kappa_y \\ \kappa_z \end{bmatrix}$$

3. What are the merits and demerits of Tsai-hill failure theory?
   The variation of strength with angle of lamina orientation is smooth rather than having cusps that are not seen in experimental results.
   The strength continuously decreases as □ grows from 0º rather than the rise in uni-axial strength that is characteristic of both the maximum stress and the max. strain criteria.
   The agreement between the criterion and experiment is even better than that at first glance. The maximum stress and strain criteria are incorrect by100% at 30º.
   Considerable interaction exists between the failure strengths X,Y,S in the Tsai-hill criterion but none exists in the previous criteria where axial, transverse and shear failures are presumed to occur independently.

4. Give examples of anti symmetric angle ply and symmetric cross ply laminates.
   Anti-symmetric angle ply
   [-40/40/-40/40]
   Symmetric cross ply laminate
   [90/0/90/0/90]

5. Define cross ply laminate and angle ply laminate.
   <u>Cross ply laminates</u>
   A laminate is called a cross ply laminate (also called laminates with specially orthotropic layers) if only 0º and 90 º plies were used to make a laminate. An example of a cross ply laminate is a (0/90/90/0/90] laminate.
   <u>Angle ply laminates</u>
   A laminate is called an angle ply laminate if it has plies of same material and thickness, and only oriented at +□ and – □ direction. An example of an angle ply laminate is [-40/40/-40/40].

6. What are the assumptions made in classical small deformation theory for a laminate?
   (i)Each lamina is orthotropic.
   (ii)Each lamina is homogeneous.
   (iii)A line straight and perpendicular to the middle surface remains straight and perpendicular to the middle surface during deformation ($\gamma_{xz} = \gamma_{xz} = 0$)
   (iv)A straight line in the z-direction remains of constant length ($\varepsilon_z = 0$).
   (v)The laminate is thin and is loaded only in its plane. (plane stress) ($\sigma_z = \tau_{xz} = \tau_{xz} = 0$)
   (vi)Displacements are continuous and small throughout the laminate.
   ($|u|$, $|v|$, $|w|$ <<laminate thickness).
   (vii)Each lamina is elastic.
   (viii)No slip occurs between the lamina inter faces.

7. Define inter laminar stresses with causes.
   In classical lamination theory no account is taken of stresses such as σ_{zx}, τ_{zx} and τ_{zy} which are shown on an element of an angle-ply laminate loaded with Nx. These stresses are called inter laminar stresses and exist on surfaces between adjacent layers although they exist within the layers but are usually largest at the layer interfaces.
   Accordingly, classical lamination theory does not include some of the stresses that actually cause failure of a composite laminate.

8. Define: Laminate code.
   A laminate is made of a group of a single layers bonded to each other. Each layer can be identified by its location in the laminate, its material and its angle of orientation with a reference axis. Each lamina is represented by the angle of ply and separated from other plies by a slash sign. The first ply is the top ply of the laminate. Special notations are used for symmetric laminates, laminates with adjacent lamina of same orientation or of opposite angles and hybrid laminates.

9. Define: Quasi-isotropic laminate.
   A laminate approximating isotropy by orientation of plies in several or more directions.

10. What is inter laminar shear?
    A shearing force tending to produce a displacement between two laminae along the plane of their interface.

11. Define the term: Balanced laminate.
A laminate in which all the plies are at angles other than 0º and 90º and occur in ±pairs. The plies are symmetrical about the centre line.

12. What are the equations of [A],[B] and [D] matrices?

$$Aij = \underset{k=1}{\overset{3}{\varepsilon}} \left[\bar{Q}_{ij} \right]_k (h_k - h_{k-1}) \text{, i= 1,2,3; j=1,2,3}$$

$$Bij = \frac{1}{2} \underset{k=1}{\overset{3}{\varepsilon}} \left[\bar{Q}_{ij} \right]_k (h_k^2 - h_{k-1}^2) \text{ i=1,2,3; j=1,2,3}$$

$$Dij = \frac{1}{3} \underset{k=1}{\overset{3}{\varepsilon}} \left[\bar{Q}_{ij} \right]_k (h_k^3 - h_{k-1}^3) \text{ ,i=1,2,3; j=1,2,3}$$

13. What are the transverse equations for laminated plates?
The equilibrium differential equations in terms of the force and moment resultants derived and the transverse loading p(x,y) are
$N_{xx} + N_{yy}=0$
$N_{xy,x}+ N_{y,y}=0$
$M_{x,xx}+2M_{xy,xy}+M_{y,yy}=-p$
Where a comma denotes differentiation of the principal symbol with respect to the principal symbol with respect to the subscript that follows the comma.

14. What is hybrid laminate?

Graphite/Epoxy	0
Boron/Epoxy	45
Boron/Epoxy	– 45
Boron/Epoxy	– 45
Boron/Epoxy	45
Graphite/Epoxy	0

$[0^{Gr}/\pm 45^{B}]_s$ denotes the above laminate. It consists of six plies but the 0º plies are made of graphite/epoxy, while the angle plies are made of boron/epoxy.

15. What is maximum strain failure theory?
This theory is based on the Maximum Normal strain theory by St. Venant and the Maximum shear stress theory by Tresca as applied to isotropic materials. The strains applied to a lamina are resolved to strains in the local axes. Failure is predicted in a lamina, if any of the normal or shearing strains in the local axes of a lamina or exceed the corresponding ultimate strains of the unidirectional lamina. Given the strains /stresses in an angle lamina, find the strains in the local axes. A lamina is considered to be failed if

$$-(\varepsilon_1^c)_{ult} < \varepsilon_1 < (\varepsilon_1^t)_{ult}$$

$$-(\varepsilon_2^c)_{ult} < \varepsilon_2 < (\varepsilon_2^c)_{ult}$$

or

$$-(\gamma_{12})_{ult} < \gamma_{12} < (\gamma_{12})_{ult}$$

16. What are the types of hybrid laminates?
Interply hybrid laminates
Intraply hybrid composites
Interply-intraply hybrids
Resin hybrid laminates

17. What is warpage of laminates?
In laminates which are not symmetric, a temperature difference results in out-of-plane deformation. This deformation is also called warpage and is calculated by integrating –displacement equation

$$\kappa_x = -\frac{\partial^2 w}{\partial x^2}$$

$$\kappa y = -\frac{\partial^2 w}{\partial y^2}$$

$$\kappa_{xy} = -2\frac{\partial^2 w}{\partial x \partial y}$$

18. What is maximum stress failure theory?
The stresses acting on a lamina are resolved into the normal and shear stresses in the local axes. Failure is predicted in a lamina, if any of the normal or shear stresses in the local axes of a lamina are equal to or exceed the corresponding ultimate strengths of the unidirectional lamina.
Given the stresses or atrains in the global axes of a lamina, one can find the stresses in the material axes . The lamina is considered to be failed if

$$-(\sigma_1^c)_{ult} < \sigma_1 < (\sigma_1^T)_{ult}$$

$$-(\sigma_2^c)_{ult} < \sigma_2 < (\sigma_2^T)_{ult}$$

or

$$-(\tau_{12})_{ult} < \tau_{12} < (\tau_{12})_{ult}$$

19. What is strength ratio?
The strength ratio is defined as

$$SR = \frac{\text{Maximum Load Which Can Be Applied}}{\text{Load Applied}}$$

The concept of strength ratio is applicable to any failure theory. If SR>1, then the lamina is safe and the applied stress can be increased by a factor of SR. If SR<1, the lamina is unsafe and the applied stress needs to be reduced by a factor of SR. A value of SR=1 implies the failure load.

20. What is 'failure envelopes'?
A failure envelope is a three dimensional plot of the combinations of the normal and shear stresses which can be applied to an angle lamina just before failure. Since drawing three-dimensional graphs can be time consuming, one may develop failure envelopes for constant shear stress, τ_{xy}, and then use the two normal stresses σ_x and σ_y as the two axes. Then if the applied stress is within the failure envelope, the lamina is safe, otherwise it has failed.

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Unit 4

1. List down the materials used for sandwich construction.
   Face material
   Core material
   Wood
   Foam
   Polyvinyl chloride foam(PVC)
   Poystyrene foams
   Polyurethane foams
   Polymethyl methacrylamide foams
   Styrene acrylonitrile (SAN) co-polymer foams

2. List down the advantages using a sandwich construction.
   Stiffness to weight ratio is high.
   Strength to weight ratio is high.
   Honeycomb sandwich panels are also used for energy absorption, air directionanlisation, acoustical and thermal versatility, radio frequency shielding etc.,
   Honeycomb is also used for straightening and directing air flow.

3. What are the three elements in a structural sandwich?
   A pair of thin and strong facing.
   A thick and light weight core to separate the facings and carry loads from one facings to the other and
   An attachment which is capable of transmitting shear and axial loads to and from the core.

4. List down the modes of failure in a sandwich structure.
   Facing failure
   Flexure crushing of core
   Local crushing of core
   General buckling
   Shear crimping
   Face wrinkling
   Intra-cell buckling (dimpling)

5. What are the different failure modes of sandwich construction?
   Facing failure
   Transverse shear failure
   Flexure crushing of core
   Local crushing of core
   General buckling
   Shear crimping
   Face wrinkling
   Intra-cell buckling (dimpling)

6. What is meant by sandwich construction?
   Two relatively thin, parallel sheets of structural material bonded to and separated by a relatively thick, light weight core.

7. Define: Shear crimping.
The column buckling caused by the core having too low a shear modulus.

8. Distinguish between face dimpling and face wrinkling.

Face dimpling	Face wrinkling
The compressive buckling of the facing in between the honeycomb walls caused by thin facings or large cell core.	The local compressive instability of facing; similar to plate buckling on an elastic foundation.

9. What is splicing?
When large core pieces or complex shapes are desired, small pieces can be spliced together with core splicing adhesives.

10. What is bonding pressure?
Adhesives such as the phenolics and some others actually require more than atmospheric pressure in order to prevent excessive porosity. Most of the core materials alone cannot withstand compressive bonding loads exceeding a few atmospheres and consequently are not fit to be used with any adhesive system requiring higher bonding pressures.

11. What is fillet forming?
In order to achieve a good attachment to an open cell core, the adhesive must have a unique combination of surface tension, surface wetting and controlled flow during early stages of cure. Controlled flow prevents the adhesive from flowing down the cell wall and leaving a low strength top skin attachment and an overweight bottom skin attachment.

12. What is adaptability?
In case of contoured parts, the adhesive must also be a good gap-filler without appreciable strength penalty, since tolerance control of details is much more difficult to achieve on contoured parts than on flat panels.

13. What is meant by flexure modulus.
The ratio, within the elastic limit, of the applied stress on a test specimen in flexure to the corresponding strain in the outermost fibers of the specimen.

14. What are the aspects must be considered in designing sandwich structures?
(a)The sandwich is a composite structure.
(b) The material used may be anisotropic
(c) The core has sufficient shear modulus.

15. What is the purpose of the attachment of core with facings?
(a) Act as single unit under deflection.
(b) Prevent separation and relative motion between the components
(c) Have sufficient strength to force failure in either the core or the facings at only the ultimate load.

16. Write short notes on : Polyvinyl chloride
Closed-cell polyvinyl chloride (PVC) foams are one of the most commonly used core materials for the construction of high Performance sandwich structures. Although, they are a chemical hybrid of PVC and polyurethane, they tend to be referred to simply as 'PVC foams'.

17. What is the needs of design guide lines in sandwich construction?
Requirements of thick facings to withstand the tensile, compressive and shear stresses induced by the design loads.
Adequate strength of the core to withstand shear stresses induced by the design loads.
Adequate compressive strength of the core to resist crushing by design loads acting normal to the panel facings or by compressive stresses induced through flexure.
Requirements of thick core having sufficient shear modulus to prevent overall buckling of the sandwich under load.

18. What is the property of toughness?
In the area of sandwich core-to–facing bonds, toughness refers to the resistance shown by the adhesive towards loads, which act to separate the facings from core under either static or dynamic conditions. Greater toughness in the bond line usually equates to greater durability and thus to longer service life.

19. Define: Foam.
The use of foam as a structural core continues to be extensive. Recent developments in the technology of foam injection have increased the use of these materials. The most novel of these methods is the use of a cold-cavity die, in which the foam is injection molded in a single production step. This is one of the core materials.

20. What are the types of honeycomb?
Paper honeycomb
Aluminium honeycomb
Glass fibre reinforced plastic honeycomb
Aramid paper honeycomb
Carbon fibre honeycomb
Kevlar honeycomb
Kevlar paper honeycomb

Unit 5

1. Explain the difference between fibers and whiskers.
   Fiber
   A fiber is characterised geometrically not only by its very high length to diameter ratio but by its near crystal sized diameter.
   Whiskers
   A whisker has essentially the same near-crystal-sized diameter as a fiber but generally is very short and stubby, although the length-to-diameter ratio can be in the hundreds. Thus a whisker is an even more obvious example of the crystal –bulk-material-property-difference paradox.

2. Distinguish between open mould and close mould processes.
   Open mould process: It is done in open structure.
   - Spray lay up
   - Hand lay up
   - Filament winding
   - SMC
   - Expansion tool moulding
   - Contact moulding

   Closed mould processes
   It is done in a closed structure.
   - Compression moulding
   - Vacuum bag
   - Injection moulding
   - Resin transfer

3. What is meant by sizing of glass fibers?
   The filaments are cooled rapidly and coated with a sizing such as starch, gelatine, oil etc. to avoid damage to the fibers. The sizing imparts strand integrity, resin compatibility, adhesion properties, etc. to the final product.

4. What is vacuum bag moulding?
   A process in which a lay-up is cured under pressure by drawing a vacuum in the space between the lay-up and a flexible sheet placed over it and sealed at the edges.

5. Define: Roving.
   Collection of bundles of continuous filaments either as untwisted strands or as twisted yarns.

6. What is pre-preg?
   It is impregnated with resin and partly cured. A combination of mat, fabric or non-woven material with resin advanced to B-stage, ready for curing.

7. What is meant by knitting?
   A method of constructing fabric by interlocking series of loops of one or more yarns.

8. State the process of injection moulding.
   Method of forming a plastic to the designed shape by forcing the heat softened plastic into a relatively cool cavity under pressure.

9. Give brief notes on: filament winding.
   A fabrication process in which continuous filament is treated with resin and wound onto a removable mandrel in a present pattern.

10. State the definition of fiber glass.
    An individual filament made by drawing molten glass. A continuous filament is a glass fiber of great of indefinite length.

11. What is facing failure?
    The sandwich panel failure caused by the facing failing in compression, tension or local buckling.

12. Explain the term: Facing.
    One of the two outer layers, which has been bonded to the core of a sandwich.

13. What is meant by cure?
    To change the properties of a thermosetting resin irreversibly by chemical reaction, i.e., condensation, ring closure, or addition. Cure may be accomplished by addition of curing (cross-linking) agents, with or without catalyst, and with or without heat and pressure.

14. Define the term: Creep.
    The time dependent part of strain resulting from an applied stress. Also referred to as the change in dimension of a material under load over a period of time.

15. What is creel?
    A framework arranged to hold tows, rovings or yarns so that many ends can be withdrawn smoothly and evenly without tangling.

16. What is 'chopped strands'?
    Short strands cut from continuous filament strands of reinforcing fibetr, not held together by any means.

17. What is the function of caul plate?
    Smooth metal plates, free of surface defects, same size and shape as that of a composite lay-up, used immediately in contact with the lay-up during the curing process to transmit normal pressure and to a smooth surface on the finished laminate.

18. What are the characteristics of carbon fiber?
    Reinforcing fiber known for its light weight, high strength and high stiffness produced by pyrolysis of an organic precursor fiber in an inert atmosphere at temperature above 1000ºC. Can also be graphitised by heat-treating above 2500ºC.

19. What is the function of bleeder cloth?
    A material used to allow the escape of gases and excess resin during cure cycle. It is removed after completion of curing cycle.

20. What are the desired properties of the matrix?
    Reduced moisture absorption.
    Low shrinkage.
    Low coefficient of thermal expansion.
    Good flow characteristics so that it penetrates the fibre bundles completely and eliminates voids during the compacting/curing process.
    Reasonable strength, modulus and elongation (elongation should be greater than fibre).
    Must be elastic to transfer load to fibers.

PartB (16 Marks) Questions with keys

Unit 1

1. Obtain an expression for E_1 , E_2, and G_{12} in terms of material properties with respect to principal material directions using mechanics of material approach.
   Ans: Refer 'Mechanics of materials approach' by Autar K.Kaw pp 159-173.

2.(a) What are the advantages of composite material? And explain its area of application?
   Ans: Refer 'Mechanics of materials approach' by Autar K.Kaw pp 28-45.

(b) Show the reduction of anisotropic material stress-strain equations to those of a monoclinic material stress-strain equations.
   Ans: Refer 'Mechanics of materials approach' by Autar K.Kaw pp 75-77.

3. For a graphite/epoxy unidirectional lamina, find the following.
   (a) Compliance matrix.
   (b) Minor poisons ratio.
   (c) Reduced stiffness matrix.
   (d) Strains in the 1-2 co-ordinate system if the applied stresses are σ_1=2MPa, σ_2= -3MPa, τ_{12}= 4MPa,
   E_1=181GPa, E_2=10.3 GPa, υ_{12}=0.28,G_{12}=7.17 GPa.
   Ans:

$$(a)\ [S]=\begin{bmatrix} 0.0055 & -0.0015 & 0 \\ -0.0015 & 0.097 & 0 \\ 0 & 0 & 0.1395 \end{bmatrix} \text{x}10^{-9}\,\text{Pa}^{-1}$$

(b) $\upsilon_{21} = 0.01593$

(c) $[Q] = \begin{bmatrix} 181.8 & 2.897 & 0 \\ 2.897 & 10.35 & 0 \\ 0 & 0 & 7.17 \end{bmatrix} x10^9$

(d) $\varepsilon_1 = 15.69 \frac{\mu m}{m}$; $\varepsilon_2 = -294.4 \frac{\mu m}{m}$; $\gamma_{12} = 557.9 \frac{\mu m}{m}$.

4. Explain the Hooke.s law for different materials?
   Ans: Refer 'Mechanics of materials approach' by Autar K.Kaw pp 67-69.

5. Explain monoclinic material with compliance and stiffness matrices.
   Ans: Refer 'Mechanics of materials approach' by Autar K.Kaw pp 70-72.

<u>Unit 2</u>

1. (a) For glass epoxy laminate $E_f = 85$ Gpa, $E_m = 3.4$ GPa, $\upsilon_m = 0.3$ and $\upsilon_f = 0.25$, find the minor Poisson's ratio υ_{21} and G_{12} for a fiber volume fraction of 70%.
   Ans; $\upsilon_{21} = 0.23$; $G_{12} = 0.03939$.

   (b) What weight of glass fibers must be added to 1kg of epoxy to produce a composite with a density of 1700 kg/m^3, $\rho_f = 2500$kg/m^3 and $\rho_m = 1200$ kg/m^3.
   Ans: Weight of glass fibers = 1.3007kg.

2.(a) Describe stress strain relations for a lamina of arbitrary orientation.
   Ans: Refer 'Advanced composite materials' by Lalit Gupta pp 115-116.

   (b) A graphite/ epoxy cuboid specimen with voids has dimensions a x b x c and its mass is Mc. After putting it in a mixture of sulphuric acid and hydrogen peroxide, the remaining graphite fibers have a mass Mf. From independent tests, the densities of graphite and epoxy are ρ_f and ρ_m, respectively. Find the volume fraction of the voids in terms of a, b, c, Mf,Mc, ρ_f and ρ_m.

   Ans.: $V_v = \frac{v_v}{abc} = 1 - \frac{1}{abc}\left[\frac{M_f}{\rho_f} + \frac{M_c - M_f}{\rho_m}\right]$

3. Explain the elasticity approach to find four elastic moduli.
   Ans: Refer 'Mechanics of materials approach' by Autar K.Kaw p180-183.

4. Explain Hooke.s law for a twodimensional unidirectional lamina?
   Ans: Refer 'Mechanics of materials approach' by Autar K.Kaw pp 80-82.

5. Find the following for a 60º angle lamina of graphite /epoxy. E_1=181GPa, E_2=10.3GPa, υ_{12}=0.28,G_{12}=7.17 GPa.
   (a) Transformed compliance matrix
   (b) Transformed reduced stiffness matrix
   If the applied stress is σ_x =2 MPa, σ_y =-3MPa, τ_{xy} = 4MPa, also find
   (c) Global strains
   (d) Local strains
   (e) Local stresses

(f) Principal stresses
(g) Maximum shear stress
(h) Principal strains
Ans:

$$\bar{\bar{S}}_{12} = -0.7878(10^{-11})\frac{1}{Pa}$$

$$\bar{\bar{S}}_{16} = -0.3234(10^{-10})\frac{1}{Pa}$$

(a) $$\bar{\bar{S}}_{22} = 0.3475(10^{-10})\frac{1}{Pa}$$

$$\bar{\bar{S}}_{26} = -0.4696(10^{-10})\frac{1}{Pa}$$

$$\bar{\bar{S}}_{66} = 0.1141(10^{-9})\frac{1}{Pa}$$

(b) $$\left[\bar{\bar{Q}}\right] = \begin{bmatrix} 0.2365 & 0.3246 & 0.2005 \\ 0.3246 & 0.1094 & 0.5419 \\ 0.2005 & 0.5419 & 0.3674 \end{bmatrix} x10^{11}\,Pa$$

(c) $$\begin{bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{bmatrix} = \begin{bmatrix} 0.5534(10^{-4}) \\ -0.3078(10^{-3}) \\ 0.5328(10^{-3}) \end{bmatrix}$$

(d) $$\begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \gamma_{12} \end{bmatrix} = \begin{bmatrix} 0.1367(10^{-4}) \\ -0.2662(10^{-3}) \\ -0.5809(10^{-3}) \end{bmatrix}$$

(e) $$\begin{bmatrix} \sigma_1 \\ \sigma_2 \\ \tau_{12} \end{bmatrix} = \begin{bmatrix} 0.1714(10^{7}) \\ -0.2714(10^{7}) \\ -0.4165(10^{7}) \end{bmatrix} Pa$$

(f) $\sigma_{max,min}$ = 4.217,-5.217 MPa
(g) τ_{max} = 4.717 MPa.
(h) $\varepsilon_{max,\ min}$ = 1.962(10^{-4}), -4.486(10^{-4})

Unit 3

1. Explain Tsai-Hill failure theory used for anisotropic materials.
Show that for unidirectional lamina the failure theory can be written as $\sigma_1^2 / X^2 - \sigma_1\sigma_2 / X^2 + \sigma_2^2 / Y^2 + \tau_{12}^2 / S^2 = 1$ where $\sigma_1, \sigma_2, \tau_{12}$ are the stress components with respect to principal material direction and X, Y and Z are failure strengths of the lamina.
Ans: Refer 'Mechanics of materials approach' by Autar K.Kaw pp 119-122.

2.(a) What are the types of laminates given below? Mention which elements of

[A],[B] and [D] are zero for each of them.

(1) [± 45 / ± 45]
(2) [30 / -45 / -30 / 45]
(3) [0 / 90 / 0 / 90]

Ans: (1) Angle ply laminate
(2) Balanced laminate
(3) Cross ply laminate and also
Refer 'Mechanics of materials approach' by Autar K.Kaw pp 269-271.

(b) Compute [A] matrix for a [0/±45] laminate with the following laminate properties. E_1 =145 GPa, E_2 =10.5 GPa, υ_{12} = 0.28 and G_{12} =7.5 GPa. Thickness of each lamina is 0.25 mm.

Ans: $$\begin{bmatrix} 6.045X10^6 & 1.728X10^6 & 0 \\ 5.55x10^5 & 2.668x10^7 & 0 \\ 0 & 0 & 2.068x10^7 \end{bmatrix}$$

3. Find the stiffness matrices [A], [B] for a three ply [0/30/-45] graphite epoxy laminate. Assume each lamina has a thickness of 5mm. The properties of graphite/epoxy E_l =181 GPa, E_t =10.3 GPa, υ_{lt} = 0.28 and G_{lt} =7.17 GPa.

Ans: $$[A] = \begin{bmatrix} 1.739x10^9 & 3.88x10^8 & 5.66x10^7 \\ 3.44x10^8 & 4.53x10^8 & -1.14x10^8 \\ 5.66x10^7 & -1.141x10^8 & 4.525x10^8 \end{bmatrix} \text{ Pa-m.}$$

$$[B] = \begin{bmatrix} -3.128x10^6 & 9.85x10^5 & -1.07x10^6 \\ 9.86x10^5 & 1.157x10^6 & -1.07x10^6 \\ -1.07x10^6 & -1.07x10^6 & 9.85x10^5 \end{bmatrix} \text{ Pa-m.}$$

4. A symmetric angle ply laminate hae the following data: 4 Layers of each 0.5mm thick +45°/-45°/-45°/+45° . E_l =210 GPa, E_t =21 GPa, υ_{it} = 0.3 and G_{it} =7 GPa. Compute the in-plane stiffness matrix of the laminate.
Ans: Refer 'Mechanics of materials approach' by Autar K.Kaw pp 237-23.

5. Derive the governing differential equation for a laminated unidirectional anisotropic plate.
Ans: Refer 'Mechanics of composite materials' by Robert M. Jones pp 290-299.

Unit 4

1(a) What are the materials used for sandwich construction.
Ans: Refer 'Advanced composite materials' by Lalit Gupta pp 68-76.

(b) Write short notes on the failure modes of sandwich panels.
Ans: Refer 'Advanced composite materials' by Lalit Gupta pp 83.

2. (a) Explain basic design concept of sandwich construction.
Ans: Refer 'Advanced composite materials' by Lalit Gupta pp 81-82.

(b) Explain the two methods of honey comb core manufacturing.
Ans: Refer 'Advanced composite materials' by Lalit Gupta pp 77-78.

3. Explain the cell configuration in honeycomb cores?
Ans: Refer 'Advanced composite materials' by Lalit Gupta pp 78-79.

4. Obtain an expression for the flexural modulus of a
(a) Sandwich plate with different face thickness.
(b) Sandwich plate with different face thickness and material.
Ans:Refer 'Mechanics of materials approach' by Autar K.Kaw pp 84-88.

5. Explain the honeycomb processes.
Ans: Refer 'Advanced composite materials' by Lalit Gupta pp 81-82.

Unit 5

1. (a) What are the functions and desirable properties of resins?`
Ans: Refer 'Advanced composite materials' by Lalit Gupta pp 33-34.

(b) Write short notes on vacuum bag moulding and continuous pultrusion.
Ans: Refer 'Advanced composite materials' by Lalit Gupta pp 201-203;215-217.

2. (a) Explain with neat sketches the production of carbon fibers.
Ans: Refer 'Advanced composite materials' by Lalit Gupta pp 15-18.

(b) What are the commercial forms of fibers?
Ans: Refer 'Advanced composite materials' by Lalit Gupta pp 9-32.

3.(a) Explain open and closed mould processes.
(b) Explain with neat sketches one fabrication process under each method.
Ans: Refer 'Advanced composite materials' by Lalit Gupta pp 189-215.

4. Explain any two methods of glass fiber manufacturing with neat sketch.
Ans: Refer 'Advanced composite materials' by Lalit Gupta pp 11-14.

5. (a) Explain the applications of resins.
Ans: Refer 'Advanced composite materials' by Lalit Gupta pp 43-44.

(b) Write short notes on Netting analysis.
Ans: Refer 'Mechanics of composite materials' by Robert M. Jones pp 253-254.

Reg. No. : 4 2 1 0 5 1 1 4 0 1 8

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B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2008.

Seventh Semester

Mechanical Engineering

ME 1014 — COMPOSITE MATERIALS

(Common to Metallurgical Engineering)

(Regulation 2004)

Time : Three hours | Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. What is the role of reinforcement composites?

2. What are the essential requirements for matrix material in the composite?

3. How fibers reinforced composite differ from dispersion strengthened materials?

4. Why thermoplastic resin more preferred than thermoplastic resins as matrix material?

5. Why high melting point metals are not preferred as matrix for metal matrix composites?

6. What are the advantages and disadvantages of ceramic matrix composites?

7. Why reinforcement is required for polymer materials?

8. What is cold isostatic pressing?

9. Give some example for composites used in missiles.

10. What is meant by pyrolization?

PART B — (5 × 16 = 80 marks)

11. (a) What are the different types of matrices used in composites? Explain about any three.

Or

(b) (i) How the properties are enhanced in the composites? Explain with an example (8)

(ii) How strengthening mechanism of composites differ from metals and alloys? (8)

12. (a) What are the general types of reinforcing materials? Explain about any three.

Or

(b) (i) Explain filament winding moulding process with a neat sketch. (8)

(ii) Write short notes on glass fibre reinforced plastics. (8)

13. (a) (i) What are the characteristics and limitations of metal matrix composites? (8)

(ii) Explain how powder metallurgy processes are used for making metal matrix composites. (8)

Or

(b) (i) Write short notes on effect of reinforcement in metal matrix composites. (8)

(ii) Explain stir casting with a neat sketch. (8)

14. (a) (i) What is the need for ceramics matrix composites? Give any two industrial applications. (8)

(ii) Explain the mechanism of sintering. (8)

Or

(b) Write advantages, limitations and applications of any four ceramic matrix composites.

15. (a) Explain why carbon-carbon composite is used in the aircraft landing gear brakes.

Or

(b) Explain any two methods to produce carbon-carbon composites.

Reg. No. :

K 4376

B.E./B.Tech. DEGREE EXAMINATION, MAY/JUNE 2009.

Seventh Semester

Mechanical Engineering

ME 1014 — COMPOSITE MATERIALS

(Common to Metallurgical Engineering and Production Engineering)

(Common to B.E. (Part-Time) Sixth Semester, Regulation 2005)

(Regulation 2004)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. What is the role of matrix and reinforcement in composites?

2. What are the properties of particle reinforced composites?

3. What are the different types of thermoplastic resins used in polymer matrix composites?

4. Why are glass fibre reinforced epoxies preferred for high technology applications over other polymer matrix composites?

5. How is the strength of metal matrix composites varies with volume fraction of its reinforcement?

6. A continuous and alligned fibre reinforced composite is to be produced consisting of 30 vol% fibres and 70 vol% matrix. The mechanical characteristics of these two materials are as follows,

   Young's modulus of fibre = 131 GPa

   Young's modulus of matrix = 2.4 Gpa.

7. What are the properties of engineering ceramic materials?

8. Explain briefly the structure of aluminium oxide.

9. Why is thermal conductivity of carbon/carbon composite a important property?

10. What are the requirements of composites used for aerospace applications?

PART B — (5 × 16 = 80 marks)

11. (a) (i) How are the properties of bulk materials enhanced by going for composites? Explain with examples. (8)

(ii) Distinguish between particle and fibre reinforced composites. (8)

Or

(b) (i) How are ceramic matrix composites superior compared to ceramic materials? Explain with examples. (8)

(ii) Give in detail the applications of metal matrix composites and polymer matrix composites. (8)

12. (a) (i) With a neat illustration, describe the reinforced reaction injection moulding process of producing polymer matrix composites. (8)

(ii) What are the various types of fibres used in making polymer matrix composites? Explain. (8)

Or

(b) (i) Explain the filament winding process of producing polymer matrix composite with neat diagram. (8)

(ii) A fibre reinforced polystyrene contains 75 wt % of borosilicate glass fibre oriented in a parallel fashion. Estimate the Young's modulus of the composite in longitudinal direction of the fibres. Given

E_f = 65 Gpa R_f = 2400 kg/m^3

E_m = 2.6 Gpa P_m = 1050 kg/m^3. (8)

13. (a) (i) Describe the processing of metal matrix composite using diffusion bonding method. (8)

(ii) Explain the squeeze casting processing of metal matrix composite. (8)

Or

(b) (i) Obtain the rule of mixtures. (8)

(ii) A tensile load of 100 N is applied to an Aluminium-Boren composite of 1 mm^2 cross sectional area. If the volume of parallel fibres is 30%, what is the stress in the fibre when the load axis is

(1) Parallel to the fibres

(2) Perpendicular to the fibres

E_f = 440 GPa

E_m = 71 GPa. (8)

14. (a) (i) What are the advantages and disadvantages of ceramic materials? Discuss. (8)

(ii) Describe the oxide and non oxide ceramic matrix materials. (8)

Or

(b) (i) Explain the different types of reinforcements used in the ceramic matrix composites with examples. (8)

(ii) How are the ceramic matrix composites prepared using hot isostatic processing? Explain. (8)

15. (a) (i) Why is oxidation protection given to carbon/carbon composites? Explain with neat diagrams. (8)

(ii) Describe the process of chemical vapour deposition of producing carbon/carbon composites. (8)

Or

(b) (i) Give an account of applications of carbon/carbon composites. (8)

(ii) Explain the sol gel technique of producing Si_3N_4/SiC composites. (8)

Reg. No. :

Question Paper Code : Q 2793

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2009.

Seventh Semester

(Regulation 2004)

Mechanical Engineering

ME 1014 — COMPOSITE MATERIALS

(Common to Metallurgical Engineering and Production Engineering)

(Common to B.E. (Part-Time) Sixth Semester Mechanical Engineering – Regulation 2005)

Time : Three hours | Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Give the advantages of fiber composites over conventional materials.

2. What is a hybrid composite? Give one example.

3. Name one thermoplastic and one thermosetting resin used as matrix material for polymer composites.

4. Draw a schematic of pultrusion process.

5. List some properties that can be calculated using the Rule of Mixtures composite containing two different fibers.

6. Draw a schematic of squeeze casting process for manufacturing MMC's.

7. Give two examples for composites produced by HIP.

8. What are the advantages of CMC's? Give one example of CMC and mention its application.

9. What is meant by chemical vapour deposition?

10. Mention one advantage and one disadvantage of carbon-carbon composites.

PART B — (5 × 16 = 80 marks)

11. (a) Discuss the different classes of composite materials with examples and application. (16)

Or

(b) Define the term composite material. Discuss in detail the need for composites. Compare the properties of composite materials over conventional materials. (16)

12. (a) (i) What are the functions of matrix reinforcement in a fiber composite? Give an account of the matrix and fiber used in PMC's. (8)

(ii) Discuss with a neat sketch the following techniques used for manufacturing PMC's : filament winding and hand-lay up process. (8)

Or

(b) (i) Discuss the different types of fibers used in PMC's. (8)

(ii) Discuss compression moulding and reinforced reaction injection moulding briefly with simple sketches. (8)

13. (a) (i) What are MMC's? Discuss the advantages, disadvantage and applications of MMC'S. (8)

(ii) Discuss any two processes for manufacturing MMC's. (8)

Or

(b) (i) What is Rule of Mixtures? Derive the rule of mixtures for calculating the Young's modulus of a fiber composite loaded parallel to the fibers. (9)

(ii) Discuss diffusion bonding and squeeze casting processes for the production of MMC's. (7)

14. (a) (i) What are CMC's? What are the advantages of CMC' s over other types of composites? Discuss the different types of CMC's with examples and applications. (9)

(ii) Discuss Hot Pressing of CMC's with a neat sketch. (7)

Or

(b) (i) What are the different types of reinforcements used in MMC's? Discuss. (8)

(ii) Discuss Hot Isostatic Pressing of CMC's with a neat sketch. What are the advantages and disadvantages of this Process? (8)

15. (a) (i) Discuss sol gel techniques in detail. (8)

(ii) How composites materials plays an vital role in aerospace application? (8)

Or

(b) (i) Discuss any one method for producing carbon-carbon composites. (8)

(ii) Discuss the important applications of carbon-carbon composites with examples. (8)
