USN		CMRIT

Scheme and solution of Internal Assessment Test 1 – Sept. 2019

Sub:	Material Science	Sub Code:	18ME34	Branch:	Mech
Date:	06/09/2019	Duration: 90 mins	Max Marks: 50	Sem / Sec:	III/ A&B

Answer any FIVE FULL Questions

		MARKS	CO	RBT
1	Define composites and classify them on the basis of reinforcements and matrix. • Definition – 2M • Classification – 8M	[10]	CO5	L2
2	With a neat sketch explain vacuum bagging process. • Diagram – 5M • Explanation – 5M	[10]	CO5	L2
3	a. State the role of matrix and fiber in a composite. • Atleast 2 roles each for matrix and reinforcement.	[04]	CO5	L2
	b. With a neat diagram explain hand layup process. • Diagram – 4M • Explanation – 2M	[06]	CO5	L2
4	Derive the expression for longitudinal young's modulus with a neat sketch • Derivation – 10M	[10]	CO5	L2
5	Calculate the volume ratio of Al and Boron in Al-Boron composite which has the Young's modulus equal to that of iron. The Young's modulus of Al, boron and iron are 71GPa, 440GPa and 210GPa respectively. • Given data – 2M • Formulae – 3M • Steps and answer – 5M	[10]	CO5	L3
6	A continuous and aligned glass fiber reinforced composite consists of 40% by volume of glass fibers having a modulus of elasticity of 69GPa and 60% by volume of polyester resin having a modulus of elasticity of 3.4GPa. Calculate the following : (a) Modulus of elasticity of the composite in the longitudinal and transverse directions. (b) If a stress of 50MPa is applied in the longitudinal direction, calculate the magnitude of the load carried by each of the fiber and matrix phases. The cross-sectional area of the composite is 250mm^2. • Given data – 2M • Formulae – 3M • Steps and answer – 5M	[10]	CO5	L3

1. Define composites and classify them on the basis of reinforcements and matrix.

A *composite material*, or *composites* for short, can be defined as a combination of two or more *constituent* materials (*individual* materials) with different physical or chemical properties, and which remain separate and distinct on a microscopic or macroscopic* level within the finished structure. In other words, the constituents do not dissolve or merge into each other, although they act together to form a single material.

Composite materials are commonly classified at two distinct levels:

1) With respect to *matrix* constituent

- Polymer matrix composite – matrix is made from a *polymer resin* material
- Metal matrix composite – matrix is made from a *metal* or *alloy*
- Ceramic matrix composite – *matrix* is made from a *ceramic material*

2) With respect to *reinforced* constituent

- Fibre reinforced composite – reinforcement is in the form of fiber (thread like structure)
- Particle (Particulate) reinforced composites – reinforcement is in the form of small particles.
- Laminated composites – reinforcement consists of layers of material held together.

2. With a neat sketch explain vacuum bagging process.

Vacuum bag moulding is used to produce high-performance laminates usually of fiber-reinforced-epoxy systems. The method is primarily suited to prepreg* materials.

To produce a part by vacuum moulding process, a mould having the shape of the desired part is prepared suitably. Refer figure 5.9. A thin layer of gel coat is applied to aid easy removal of the cured component from the mould. The prepreg material, or layers of prepreg material depending upon the desired thickness, is stacked in the required orientation in the mould. The layer is covered by a airtight flexible sheet, or bag (frequently rubber), which is sealed around the edges of the mould by a sealant.

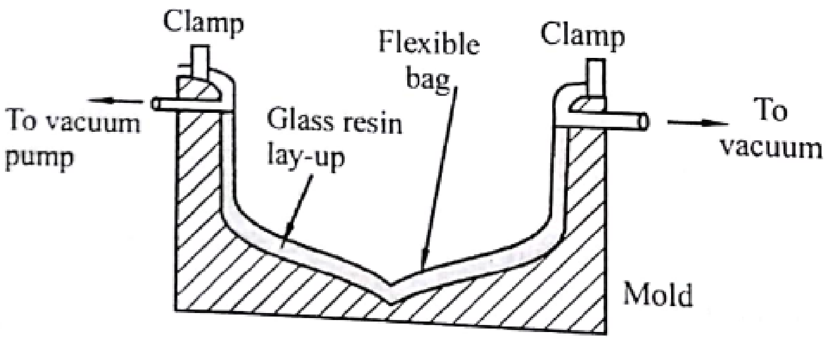

Figure 5.9 Vacuum bag moulding

Vacuum bag moulding

Vacuum is drawn from the lay-up (under the bag) with the help of a pump. In other words, the space between the bag and the mould is evacuated so that atmospheric pressure (up to 1 Bar) is applied over the surface of the lay-up. The vacuum created results in the elimination of voids, entrapped air and excess resin while producing a compact effect on the lay-up. The lay-up is

* *Prepregs are rolls of uncured composite materials which consists of a reinforcement material (long carbon fibers) pre-impregnated with a resin matrix in controlled quantities, i.e., they already contain an amount of the matrix material used to bond them together and to other components during manufacture.*

allowed to cool to the room temperature and then ejected out of the mould. To reduce the curing time, an oven may be employed.

Advantages

- Simple in operation.
- Both large and small components can be manufactured.
- Can produce laminates with a uniform degree of consolidation, while at the same time removing entrapped air, thus reducing the finished void content.
- High reinforcement to resin ratio can be achieved, i.e., higher fiber content laminates can be produced.

Disadvantages

- Labour intensive and operator dependent.
- Problems in disposable bagging materials.
- Primarily suited for prepreg materials.

Applications An important process used in aircraft and aerospace, and other low temperature applications. For example, the technique has been used to make automobile body, aircraft component, and prototype molds for certain process.

3.a. State the role of matrix and fiber in a composite.

- Holds the reinforcement material together and keep them aligned in a predetermined direction.
- Protects the reinforcement from mechanical and environmental attack.
- Distributes the loads evenly between the reinforcement material so that the entire reinforcement is subjected to the same amount of strain.
- Provides shape and form to the composite material.
- Improves impact and fracture resistance of the composite material.
- Helps to avoid propagation of crack growth through the reinforcement by providing alternate failure path along the interface between the reinforcement and the matrix.
- Carry interlaminar shear.

b) Role of Reinforcement

In a composite, the reinforcement performs the following functions:

- Carry the load and provide strength and stiffness to the composite.
- Helps the composite to obtain the desired property in the direction preferred.
- Serve certain additional purpose of heat resistance or conduction, resistance to corrosion, and provide rigidity to the composite. Reinforcement can be made to perform all or one of these functions as per the requirements.
- Reinforcement helps to deflect the crack front in matrix thereby restricting crack growth.

3. b. With a neat diagram explain hand layup process.

Hand lay-up is the simplest and the oldest method of fabricating fiber reinforced plastic. The process is shown in its simplest form in figure 5.7.

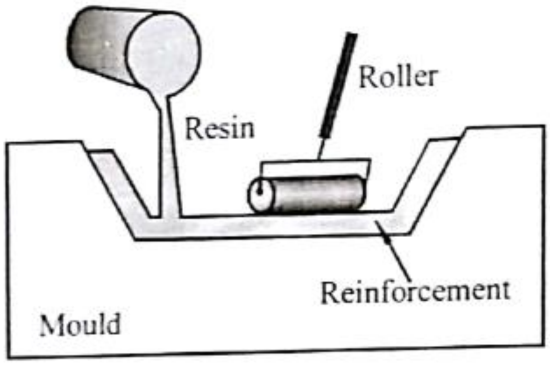

Figure 5.7 Hand lay-up process

To produce a part, a mould having the shape of the desired part is initially made of wood, wax, clay, or plastics. A gel coat is applied to the open mould so that the finished component can be easily stripped from the mould without adhering to it. The fiber glass reinforcement which is normally in the form of a woven cloth, chopped strand, or mat is manually placed in the mould. The plastic resin (matrix), usually epoxy, polyster, or phenolic resin mixed with catalysts and accelerators is then applied by pouring or brushing. Rollers or squeezers are used to thoroughly wet the reinforcement with the resin matrix material to enable good compaction, and also to remove entrapped air. To increase the thickness of the composite being produced, successive layers of fiber glass mat and resin may be added as desired. The mould is allowed for a certain duration to complete full curing of the composite. The finished composite is then removed carefully from the mould.

4. Derive the expression for longitudinal young's modulus with a neat sketch

... Longitudinal Young's Modulus

Consider a composite with single fiber subjected to a tensile load P along the longitudinal axis of the fiber as shown in figure 5.23.

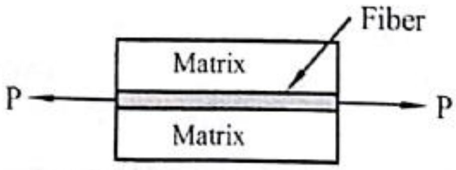

Figure 5.23

The total load acting on the composite is shared equally by the fiber and the matrix.

$$\text{i.e., } P_C = P_f + P_m \qquad \text{-----(1)}$$

where subscripts c, f & m denote composite, fiber & matrix respectively.

$$\sigma_C A_C = \sigma_f A_f + \sigma_m A_m \qquad \left(\because \text{stress } \sigma = \frac{Load(P)}{Area(A)} \right)$$

$$\sigma_C = \sigma_f \left(\frac{A_f}{A_C} \right) + \sigma_m \left(\frac{A_m}{A_C} \right)$$

$$\sigma_C = \sigma_f V_f + \sigma_m V_m \qquad \text{-----(2)}$$

where $V_f = \frac{A_f}{A_C}$ = Volume fraction of fiber and $V_m = \frac{A_m}{A_C}$ = Volume fraction of matrix

$$\text{w.k.t. } \frac{stress(\sigma)}{strain(\varepsilon)} = \text{Youngs modulus } (E)$$

$\therefore$ equation (2) reduces to, $E_C \varepsilon_C = E_f \varepsilon_f V_f + E_m \varepsilon_m V_m$ -----(3)

Under the assumption that the fiber is rigidly bonded to the matrix, no stiffness occurs at the interface and as such both the fiber and matrix will experience uniform strain, i.e., $\varepsilon_f = \varepsilon_m$

$$\therefore \quad \varepsilon_C = \varepsilon_f = \varepsilon_m$$

This condition is known as *iso-strain* condition.

$\therefore$ Equation (3) reduces to, E_C or $(E_C)_1 = E_f V_f + E_m V_m$ -----(4)

Subscript 1 in equation (4) refers to longitudinal direction

Equation (4) is known as the rule of mixtures for finding Youngs modulus of composite material when loading is in the direction of fibers.

> ***Note*** The following equations help to know how the applied load is shared between the individual constituents of the composite material.
>
> **1) Ratio of load shared between fiber & matrix** $= \frac{P_f}{P_m} = \frac{E_f V_f}{E_m V_m}$
>
> **2) Fraction of load carried by fibers** $= \frac{P_f}{P_C} = \frac{E_f V_f}{E_f V_f + E_m V_m}$
>
> **and fraction of load carried by matrix** $= \frac{P_m}{P_C} = \frac{E_m V_m}{E_f V_f + E_m V_m}$
>
> The above two equations are derived in Problem No. 7 & 8, Section 5.16.

5. Calculate the volume ratio of Al and Boron in Al-Boron composite which has the Young's modulus equal to that of iron. The Young's modulus of Al, boron and iron are 71GPa, 440GPa and 210GPa respectively.

Solution : In the given composite material, aluminum is the matrix and boron fiber is the reinforcement.

By data, Young's modulus $(E_C)_{Al-b} = (E_C)_{Fe}$

$$E_{Al} = 71\ GPa, \quad E_b = 440\ GPa, \quad E_{Fe} = 210\ GPa$$

To find volume ratio $\frac{V_{Al}}{V_b}$

Assuming loading in the longitudinal direction, we have $E_C = E_f V_f + E_m V_m$

$$\text{i.e., } (E_C)_{Al-b} = 440\ V_b + 71\ V_{Al}$$

$$210 = 440\ V_b + 71\ V_{Al} \qquad \text{-----}(1)$$

$$\text{w.k.t. } V_m + V_f = 1$$

$$\text{i.e., } V_{Al} + V_b = 1 \quad \text{or} \quad V_{Al} = 1 - V_b \qquad \text{-----}(2)$$

Substituting equation (2) in (1), we get $210 = 440\ V_b + 71\ (1 - V_b)$

$$210 = 440\ V_b + 71 - 71\ V_b$$

$$139 = 396\ V_b$$

$$\text{or } V_b = \frac{139}{369} = 0.376 \qquad \mathbf{V_b = 0.376}$$

From equation (2), we get $V_{Al} = 1 - (0.376) = 0.624$ $\qquad \mathbf{V_{Al} = 0.624}$

$$\therefore \text{ Volume ratio of } Al \text{ \& boron} = \frac{V_{Al}}{V_b} = \frac{0.624}{0.376} = 1.66$$

$$\frac{V_{Al}}{V_b} = \mathbf{1.66}$$

6. A continuous and aligned glass fiber reinforced composite consists of 40% by volume of glass fibers having a modulus of elasticity of 69GPa and 60% by volume of polyester resin having a modulus of elasticity of 3.4GPa. Calculate the following : (a) Modulus of elasticity of the composite in the longitudinal and transverse directions. (b) If a stress of 50MPa is applied in the longitudinal direction, calculate the magnitude of the load carried by each of the fiber and matrix phases. The cross-sectional area of the composite is 250mm^2.

Solution :

Step 1 Data

Volume fraction of glass fibers $= V_f = 40\% = 0.4$

$$E_f = 69\ GPa = 69 \times 10^3\ N/mm^2$$

Volume fraction of matrix resin $= V_m = 60\% = 0.6$

$$E_m = 3.4\ GPa = 3.4 \times 10^3\ N/mm^2$$

Stress applied to composite $= \sigma_C = 50\ \text{MPa} = 50\ N/mm^2$

$$A_C = 250\ mm^2$$

Step 2 To find modulus of elasticity of composite (E_C)

Case 1 To find $(E_C)_1$ in longitudinal direction

w.k.t. $(E_C)_1 = E_f\, V_f + E_m\, V_m = [(69 \times 10^3)\, 0.4] + [(3.4 \times 10^3)\, 0.6] = 29.6 \times 10^3$

$\therefore$ $\mathbf{(E_C)_1 = 29.6 \times 10^3\ N/mm^2}$ or $\mathbf{29.6\ GPa}$

Case 2 To find $(E_C)_2$ in transverse direction

$$\text{w.k.t. } (E_C)_2 = \frac{E_f\, E_m}{E_f\, V_m + E_n V_f} = \frac{(69 \times 10^3)(3.4 \times 10^3)}{[(69 \times 10^3)0.6] + [(3.4 \times 10^3)(0.4)]} = 5.48 \times 10^3$$

or $\mathbf{(E_C)_2 = 5.48 \times 10^3\ N/mm^2}$ or $\mathbf{5.48\ GPa}$

Step 3 To find load carried by matrix and fiber (P_f & P_m)

$$\text{w.k.t. ratio of loads } \frac{P_f}{P_m} = \frac{E_f V_f}{E_m V_m} = \frac{(69.10^3)0.4}{(3.4 \times 10^3)0.6} = 13.52$$

or $P_f = 13.52\ P_m$ - - - - - (1)

w.k.t. Total load $= P_C = P_f + P_m$

using equation (1) we get $P_C = 13.52\ P_m + P_m$ or $P_C = 14.52\ P_m$ - - - - - (2)

To find load on composite P_C

w.k.t. $\sigma_C = \dfrac{P_C}{A_C}$ $\therefore$ $P_C = \sigma_C A_C = 50 \times 250 = 12.5 \times 10^3 N$

Now equation (2) becomes, $12.5 \times 10^3 = 14.52\ P_m$ or $\mathbf{P_m = 860.8\ N}$

From equation (1), we have $P_f = 13.52\ (860.8) = 11638$ or $\mathbf{P_f = 11638\ N}$