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Analysis Of Mechanical Properties And Free Vibration Response Of Composite Laminates

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The Word composite consisting of two or more distinct materials, having two or more distinct phases with different physical properties are noticeable different from the constituent properties. Of all composite materials the fabric type has evoked the most interest among embedded in matrix materials to form laminated composites. These have been used for centuries and today industrial innovation improved energy planning. Uncertain availability and ever increasing cost have created a greater interest in composites. The engineering importance of a composite material is that two or more distinctly different materials with dissimilar characteristics combine together to form a composite that is either superior or important in some other manner to the properties of the individual materials. Most of the composites have been created to improve combinational of mechanical characteristics such stiffness, wear resistance and mechanical properties.

The research and development of high performance structural material for aerospace and automobile have long been focused and the weight saving and minimal environmental impact. Hence light weight characteristics in structural materials have become one of the basic requirements of the transportation system. These composite panels are subjected to vibration during transportation and hence the dynamic behavior of composite laminates has been an objective of many research studies.

In the research, I investigated free vibration and the effect of stacking sequence on tensile, impact and absorption properties of composite laminates has been investigated experimentally.

1.6. Mechanics of Composite Materials

The physical properties of composite materials are generally not isotropic in nature. For instance, the stiffness of a composite panel will often depend upon the directional orientation of the applied forces and/or moments. In contrast, an isotropic material has the same stiffness regardless of the directional orientation of the applied forces and/or moments. The relationship between forces/moments and strains/curvatures for an isotropic material can be described with the following material properties: young's modulus, the shear modulus and the poisson's ratio, in relatively simple mathematical relationships. for the anisotropic material, it requires the mathematics of a second order tensor and can require up to 21 material property constants. for the special case of orthogonal isotropy, there are three different material property constants for each of young's modulus, shear modulus and poisson's ratio for a total of 9 material property constants to describe the relationship between forces/moments and strains/curvatures.

1.7. Categories of Fiber Reinforced Composite Materials

Fiber reinforced composite materials can be divided into two main categories normally referred to as short fiber reinforced materials and continuous fiber reinforced materials. Continuous reinforced materials will often constitute a layered or laminated structure.

Shocks, impact, loadings or repeated cyclic stresses can cause the laminate to separate at the interface between two layers, a condition known as delaminating. Individual fibers can separate from the matrix e.g. fiber pull-out.

Fiber Reinforced Polymers (FRPs):

- Classified by type of fiber:
  - Wood (cellulose fibers in a lignin and hemi cellulose matrix)
  - Carbon-fiber reinforced plastic or CFRP
  - Glass-fiber reinforced plastic or GFRP
- Classified by matrix:
  - Thermoplastic Composites
    - Short fiber thermoplastics
    - Long fiber thermoplastics or long fiber reinforced thermoplastics
    - Glass mat thermoplastics
    - Continuous fiber reinforced thermoplastics (e.g. Reinforced Thermoplastic pipe)

- Thermoset Composites

1.8. OBJECTIVES

The objectives of the projects are,

1. Fabrication of the glass fiber reinforced epoxy composite laminates.
2. Fabrication of vibration test fixture for vibration analysis.
3. Conducting the experiment on tensile strength, impact strength and water absorption test.
4. Conducting the experiment for vibration analysis by FFT analyzer.

MATERIALS AND EXPERIMENT

3.1 GLASS FIBERS

Glass fibers are the most common of all reinforcing fibers for polymeric matrix composites (PMC). The principal advantages of glass fibers are low cost, high tensile strength, high chemical resistance, and excellent insulating properties. The disadvantages are relatively low tensile modulus and high density (among the commercial fibers), sensitivity to abrasion during handling (which frequently decreases its tensile strength), relatively low fatigue resistance, and high hardness (which causes excessive wear on molding dies and cutting tools). The two types of glass fibers commonly used in the fiber-reinforced plastics (FRP) industry are E-glass and S-glass. Another type, known as C-glass, is used in chemical applications requiring greater corrosion resistance to acids than is provided by E-glass. E-glass has the lowest cost of all commercially available reinforcing fibers, which is the reason for its widespread use in the FRP industry. S-glass, originally developed for aircraft components and missile casings, has the highest tensile strength among all fibers in use. However, the compositional difference and higher manufacturing cost make it more expensive than E-glass. A lower cost version of S-glass, called S-2-glass, is also available. Although S-2-glass is manufactured with less-stringent nonmilitary specifications, its tensile strength and modulus are similar to those of S-glass.

Glass fibers - fig

Table: -Properties of glass fiber

Type	SiO2	Al2O3	CaO	MgO	B2O3	Na2O
E-glass	54.5	14.5	17	4.5	8.5	0.5
S-glass	64	26	-	10	-	-

3.2 EPOXY RESIN

Epoxy resin is formed out of chemical reaction between bisphenol and epichlorohydrin. To speed up the reaction and also to form effective cross linking, curing agents like aliphatic or aromatic amines or acid anhydrides are added.

Epoxy or **Polyepoxide** is a thermosetting epoxide polymer that cures (polymerizes and cross links) when mixed with a catalyzing agent or "hardener". Most common epoxy resins are produced from a reaction between epichlorohydrin and bisphenol-A.

Epoxy adhesives are a major part of the class of adhesives called "Structural Adhesives" or "Engineering Adhesives" (which also includes polyurethane, acrylic, cyanoacrylate, and other chemistries.) These high performance adhesives are used in the construction of aircraft, automobiles, bicycles, golf clubs, skis, snow boards, and other applications where high strength bonds are required. Epoxy adhesives can be developed that meet almost any application. They are exceptional adhesives for wood, metal, glass, stone, and some plastics. They can be made flexible or rigid, transparent or opaque/colored, fast setting or extremely slow. Epoxy adhesives are almost unmatched in heat and chemical resistance among common adhesives. In general, epoxy adhesives cured with heat will be more heat- and chemical-resistant than when cured at room temperature. Epoxies are sold in hardware stores, typically as two component kits. They are also sold in boat shops as repair resins for marine applications. Epoxies typically are not used in the outer layer of a boat because they are deteriorated by exposure to UV light. They are often used during boat repair and assembly, and then over coated with conventional or two pot polyurethane paint or marine varnishes that provide UV protection.

Epoxy is a copolymer; that is, it is formed from two different chemicals. These are referred to as the "resin" and the "hardener". The resin consists of monomers or short chain polymers with an epoxide groupat either end. Most common epoxy resins are produced from a reaction between epichlorohydrin and bisphenol-A, though the latter may be replaced by similar chemicals. The hardener consists of polyamine monomers, for example Triethylenetetramine (TETA). When these compounds are mixed together, the amine groups react with the epoxide groups to form a covalent bond. Each NH group can react with an epoxide group, so that the resulting polymer is heavily crosslinked, and is thus rigid and strong.

The process of polymerization is called "curing", and can be controlled through temperature, choice of resin and hardener compounds, and the ratio of said compounds; the process can take minutes to hours. Some formulations benefit from heating during the cure period, whereas others simply require time, and ambient temperatures.In this , the resin used - LY556 RESIN . LY556 resin is a bifunctional epoxy resin ie., diglycidylether of bisphenol-A (DGEBA).

3.3 PREPARATION OF RESIN MIX

The resins are stored at low temperatures with stabilizers added to it. This is done to prevent gelling. The resins are in the liquid state. Choice of resins depends upon application and economics. All these resins require hardner to start curing action. Hence, just before the application, correct quantities of hadrner should be added. Only when hardner is added, curing action or gelling will start.

In this , the hardner used:-HY951 HARDNER:-this is an aliphatic primary amine, viz., triethylene tetramine – TETA.

Before bonding at room temperature and adhesives made from mixture LY556 resin and HY951hardner mixed in the ratio of 10:1 by weight.

3.4 PREPERATION OF SPECIMEN:

PROCEDURE: By oven glass cloth laminate is commercially available is used for making laminates. The cloth was trimmed to correct size. The surface thoroughly cleaned In order to ensure free from oil, dirt, impurity etc. Before bonding at room temperature and adhesives made from mixture LY556 resin and HY951hardner mixed in the ratio of 10:1 by weight then applied Hand layup technique is used to prepare laminates. Laminates allowed to cure for 24hrs at room temperature. Fabrication is done according to ASTM D4762-10.

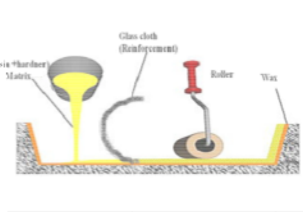


Fig 3.41. Hand lay up technique

Hand Lay-up is an open molding process. Mold release agent and gel coat are applied to the mold followed by fiber glass strands, mat, or woven roving. Thermosetting resin with a curing agent is applied to the fiber glass reinforcement. Air is removed by roller to insure complete wet out and wet through.

3.13 MAKING OF GRID POINTS:

According to the test condition make the grid points on the specimen with equal distance by the help of measuring n.Instruments at each condition the node points are given below

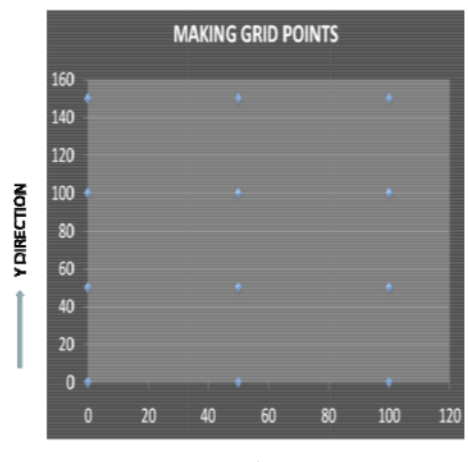


Fig 3.13, Making grid points

3.14 FIXING OF THE SPECIMEN

Fixing of the specimen according to two conditions for the experiment,

1. One end is fixed (Cantilever)
2. Both ends are fixed

3.15 EXPERIMENTAL PROCEDURE FOR VIBRATION ANALYSIS

Impact test specimen

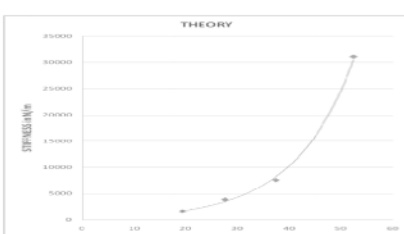
Name	Value	Unit
GG-1	24	KJ/m²
GG-2	26	KJ/m²
GG-3	28	KJ/m²
GG-4	31	KJ/m²

Results for impact test

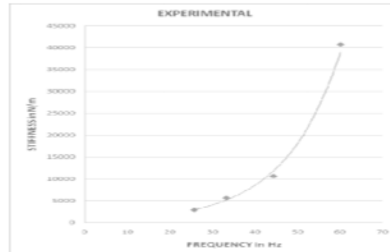
4.53 COMPARATIVE RESULTS

Laminates (Thickness in mm)	Mass in kg	Cantilever					Both end fixed				
		Frequency in Hz		Stiffness in N/m		Damping ratio	Frequency in Hz		Stiffness in N/m		Damping ratio
		Theoretical	Experimental	Theoretical	Experimental		Theoretical	Experimental	Theoretical	Experimental	
3.0	0.11	19.45	25.72	1642.8	2872.7	1.08	110.42	123.52	52.94 x 10^3	66.25 x 10^3	0.85
4.0	0.129	27.62	33.22	3885.1	5620.1	1.27	156.99	162.45	125.5 x 10^3	134.3x 10^3	1.07
5.0	0.137	37.45	44.27	7585.4	10599.8	2.4	212.9	230.53	245.1x 10^3	287.4x 10^3	1.53
8.0	0.285	52.55	60.16	31070.6	40721.1	5.5	298.74	313.69	1004.1 x 10^3	1107.1x 10^3	1.85

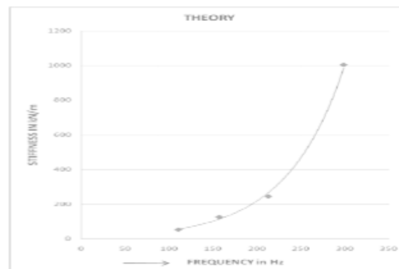
Comparative results



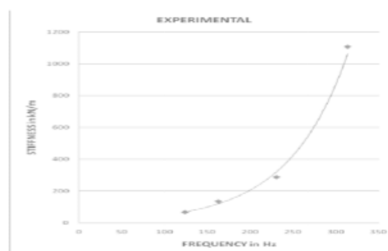
Theoretical comparison for cantilever



Experimental comparison for cantilever



Theoretical comparison for both end fixed



Experimental comparison for both end fixed

As indicated from the results table & the graphs, the frequency of vibration is the highest for the Fixed-Fixed case, followed by Free-Free and lowest for cantilever. A particular trend is observed in all the cases during the experimentation.

Fixed-fixed case has the highest frequency because of the high stiffness offered by fixing both ends. From basic vibration theory, high stiffness results in a high frequency of vibration. Since the rigidity of the system drops in the case of the cantilever, the decrease in *frequency*.

Also, as is seen in the graphs below, there is an increase in the values of frequency between cantilever and both end fixed. This is as expected, and is the nature of behavior for modal systems.

CONCLUSION

Effect of stacking sequence on tensile, impact, water absorption and vibration analysis of glass fiber reinforced epoxy composites have been experimentally evaluated. From results of this study the following conclusions are drawn,

1. Fabrication of laminated composites consisting of Glass fiber as per ASTM Standard procedure were carried out.

2. Fabrication of vibration test fixture in order to facilitate the mounting of specimens were successfully carried out.

3. Layering sequence significantly affects the tensile strength i.e the sample GG1 and GG4 of tensile strength is 13.447 KN/m^2 and 17.236 KN/m^2 respectively.

4. For the same weight fraction glass fiber layering has little effect on impact strength i.e GG1 and GG4 of impact strength is 24KJ/ m^2 and 31 KJ/ m^2 respectively.

5. Increasing the thickness of the specimens results in an increase in the natural frequency of the composite panel (directly proportional to the stiffness of the member).

6. The boundary conditions also had a considerable effect on the natural frequency of the composite panel. This information can be effectively used to design composite panels accordingly.

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