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FABRICATION AND CHARECTERIZATION OF POLYMER LAMINATE COMPOSITES REINFORCED WITH Bi – WOVEN GLASS FIBERS

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ABSTRACT

The present engineering applications are required a great demand for new and better materials for their continuous developments of existing one. In view of this demand, at present we are focused on latest upcoming materials such as composite materials. The composites are having the greatest strength to weight ratio compared with conventional materials. The engineering applications in particular aircraft and aerospace applications always seeking for new composite materials in their fabrication .Fibre reinforced polymer composites has been used in a variety of application because of their many advantages such as relatively low cost of production, easy to fabricate and superior strength compare to neat polymer resins. Reinforcement in polymer is either synthetic or natural. Synthetic fiber such as glass, carbon etc. has high specific strength but their fields of application are limited due to higher cost of production.

The present project is an attempt to do work done in the area of characterization of Glass Fibre/Epoxy composite material. Different manufacturing processes are used for making Glass Fibre/Epoxy composite the mechanical properties such as hardness, tensile strength, tensile modulus, ductility, and peak load of the composites are determined as per ASTM standards. The mechanical properties were improved as the fibers reinforcement content increased in the matrix material.

Glass fibers reinforced polymer composites have been prepared by various manufacturing technology and are widely used for various applications.Continues glass fibers were first manufactured in the 1930s for high-temperature electrical application. Nowadays, it has been used in electronics, aviation and automobile application etc. Glass fibers are having excellent properties like high strength, flexibility, stiffness and resistance to chemical harm. It may be in the form of roving's, chopped strand, yarns, fabrics and mats. Each type of glass fibers have unique properties and are used for various applications in the form of polymer composites. The behaviour under tensile, compression, impact, hardness and flexural loading of the laminates prepared by hand layup processes of Glass Fiber/Epoxy composite are the main areas of interest of this project.

1.1 Introduction

Continuous advancements in the manufacturing methodologies and performance of fiber reinforced polymer (FRP) have led to a significant growth in its market acceptance. The fabrication of composites is a complex process and it requires the simultaneous consideration of various parameters, such as component geometry, layering sequence, production volume, reinforcement & matrix types, tooling requirements, and process economics. The availability of choices makes it imperative that the factors of economics, design and manufacturing be integrated during the development process itself. For composites to become competitive with metals, cost reduction is a necessity, besides durability, maintainability and reliability.

The multitude of tasks involved in the manufacturing of composite laminates can be divided into two stages:

(1) Fabrication/manufacturing techniques and

(2) Processing methodologies.

1.2 Fabrication/Manufacturing Techniques

The fiber and matrix may be in a pre-impregnated form, or the fiber and matrix material may be combined for the first time, during this step of developing the structural form. Fabricati on techniques for composites are not dependent on the type of matrix material. In fact, some metal forming techniques have been adapted to composites fabrication, whereas, the processing conditions are entirely dependent on the type of matrix material used.In the present experimental study, a brief introduction to the manufacture of composites by using the hand lay-up process, and the issues related to manufacturing are presented and discussed in detail.

Composite materials produce a combination properties of two or more materials that cannot be achieved by either fiber or matrix when they are acting alone. Fiber-reinforced composites were successfully used for many decades for all engineering applications. Glass fiber-reinforced polymeric (GFRP) composites was most commonly used in the manufacture of composite materials. The matrix comprised organic, polyester, thermostable, vinyl ester, and phenolic and epoxy resins. Polyester resins are classified into bisphenolic and ortho or isophtalic. The

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mechanical behaviour of a fiber-reinforced composite basically depends on the fiber strength and modulus, the chemical stability, matrix strength and the interface bonding between the fiber/matrix to enable stress transfer. Suitable compositions and orientation of fibers made desired properties and functional characteristics of GFRP composites was equal to steel, had higher stiffness than aluminium and the specific gravity was one-quarter of the steel.

1.3 Processing Methodologies

The different mechanisms were used to identify the degradation of material such as initiation, propagation, branching and termination. Epoxy resins have been widely used for above applications that have high chemical/corrosion resistance properties, low shrinkage on curing. The capability to be processed under various conditions and the high level of crosslinking epoxy resin networks led to brittle material. Energy dissipation of composite was important when they were subjected to vibration environment.

Several factors influenced the energy dissipation of FRP composites such as fiber volume, fiber orientation, matrix material, temperature, moisture and others like thickness of lamina and thickness of the composites. All polymeric composites have been temperature-dependent mechanical properties. The dynamic stability of polymer matrix composites like the storage modulus and damping factors were essential to investigating under cold and higher temperature. Four different techniques were used for determining the damping based on time domain and frequency domain methods.

The time domain method was considered in logarithmic decrement analysis and Hilbert transform analysis. The moving block analysis and half power bandwidth method were considered in the frequency method.

2. LITERATURE REVIEW

This section stresses on the research work that has already been carried out for testing the mechanical properties of the Natural Fiber Reinforced Hybrid composites. Literature review of such work needs to be done in order to understand the background information available, the work already done and also to show the significance of the current project.

P Nur, M Akram Husain, ShahinSultana, M Mamunmollah et al, studied the use of natural fiber as reinforcing material is the latest invention of polymer science in order to get higher strength with lower weight composite materials having several applications. Low density polyethylene (LPDE) – banana fiber reinforced composites were prepared using both untreated and bleached (treated) banana fiber and LDPE with 7.5, 15, 33.5 and 30% weight content of fibers using compression molding technique.

3.1 MATERIALS

In this project glass fibers are used for fabricating the composite specimen. The glass fibers were obtained from Dharmapuri District, Tamil Nadu, and India. Polyester resin and the catalyst Methyl Ethyl Ketone Peroxide (MEKP) were purchased from M/s. Sakthi fiber glass Ltd., Chennai, India. 10% of catalyst is added with the resin for the quantity taken. The are different types of fibers the glass fibers used for the composite fabrication are presented in Fig.a.


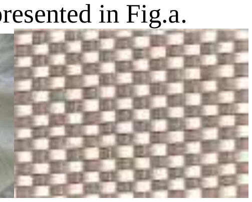

Fig 3.1: Bi-woven glass fiber Fig 3.3: close view of bi-woven fibers


Fig 3.3: Epoxy resin Fig 3.4: MEKP catalyst

3.2 Structure, chemistry, and synthesis of epoxy resin

DGEBA is a typical commercial epoxy resin. The oxirane functional group (a three-member ring formed between two carbon atoms and an oxygen) is the main feature of the epoxy monomer. Figure 1(a) and (b) shows the 3-D oxirane ring of epoxy and resulting cross-linked structure of cured epoxy. Because of the different electronegativity of carbon and oxygen, the carbon atoms of the ring are electrophilic. This atomic arrangement shows enhanced reactivity because of their high strain, compared with common ethers. Epoxy resins, depending on their backbone structure, may be of low- or high-viscosity liquids or solids. In low-viscosity resin, a decent wetting of fibers by the resin without using high temperature or pressure can be achieved. But the impregnation of fibers with high-viscosity resins is usually done through high temperature and pressure. Nowadays, almost 90% of the world production of epoxy resins is based on the reaction between BPA and epichlorohydrin in the presence of a basic catalyst, producing major DGEBA.

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Table 1. Characteristic Bands Of DGEBA In The Mid – IR

Table 1. Characteristic bands of DGEBA in the mid-IR.[11]

Resin	Band (cm^{-1})	Assignment
DGEBA	3500	O–H stretching
	3057	Stretching of C–H of the oxirane ring
	2965–2873	Stretching C–H of CH_2 and CH aromatic and aliphatic rings
	1608	Stretching C = C of aromatic rings
	1509	Stretching C–C of aromatic rings
	1036	Stretching C–O–C of ethers
	915	Stretching C–O of oxirane group
	831	Stretching C–O–C of oxirane group
	772	Rocking CH_2

DGEBA: diglycidyl ether of bisphenol A.

3.3 Advantages of epoxy over thermoplastics such as the following:

- ❖ Minimum shrinkage during curing
- ❖ Relatively cheaper and abundant
- ❖ Improved mechanical and fatigue strength
- ❖ Outstanding moisture resistance
- ❖ Outstanding chemical resistance
- ❖ Better electrical properties

3.4 Commercial applications of epoxy resin

Some of the important applications involving epoxy resins are as follows:

- ❖ Adhesives for general purposes
- ❖ Binder in cements and mortars
- ❖ Making rigid foams
- ❖ For non-skid coatings

Recent years have witnessed a huge interest in developing the polymers derived from renewable resources in industrial applications because of growing environmental issues, waste disposal, and depletion of non-renewable resources. The advantages of biopolymers includes low production cost and their possible biodegradability. DGEBA is derived from BPA and epichlorohydrin; thus, the easiest way to obtain a partially bio-based DGEBA is to use epichlorohydrin from bio based glycerol, an abundant and inexpensive polyol. Such bio-based epichlorohydrin is commercially available. The challenge to obtain a wholly bio-based epoxy pre polymer still persists, as the molar mass of DGEBA is dominated by BPA, whereas the epichlorohydrin parts accounts only for 30%, but it can be overcome, by replacing BPA with a bio-based polyol.

3.5 Modification of epoxy resin

The potential use of epoxy thermosets in many high-performance applications is limited because of some of their structural drawbacks. However, to overcome the epoxy resins weak point, virtually all of the epoxy resins are modified/amended with various additives and fillers, such as reactive oligomeric compounds, low molecular weight polymers, plasticizers, nano-particles, nano-fillers, and carbon nanotube. Significant property improvements are made by,

- ❖ Using curing agents, resins, and co-monomers with new backbone chemistries.
- ❖ Modification with thermoplastic polymer, elastomers, inorganic particles, continuous or chopped fibers (glass, carbon, aramid, or natural fibers), different geometry (particles, fibers, or platelets) and of different size (micro and nano).

In composite laminates, fibres exist in various forms and are generally described under the aegis of fibre ply or layer. Fibre plies are available in three different forms, namely: tape, weaving fabric and knitting or stitching plies. Tape is the unidirectional ply (see Plate 4a). It has fibres arranged parallel to one another facing a single direction. Such composites produced from a tape fibres have a high specific strength along a single direction and are stronger than woven fabrics. Woven fabric are the bidirectional fibres (see Plate 4b). Fibres are weaved both along longitudinal and transverse directions to assume an angle 900 ply. This ply maintains fibre orientation and more flexible for lay up of complex shapes than tape; it gives rise to lighter composites with reduced characteristic resin void size. Woven fabrics are generally of two types, namely; plain and satin fabrics.Sandwiched panel composites (see Plate 5) having a central core which is adhesively bonded to two outer sheets..

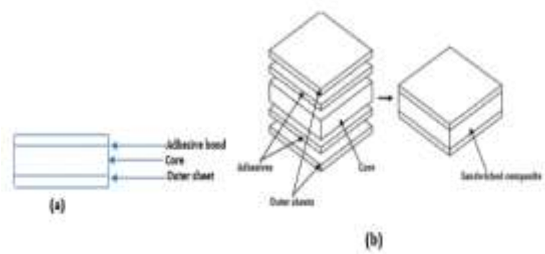

Fig 3.5 Computer Image Of Sandwiched Composites

3.6 METAL MATRIX COMPOSITES (MMC)

Metal matrix composites, as the name implies, have a metal matrix. Examples of matrices in such composites include aluminium, magnesium and titanium. The typical fiber includes carbon and silicon carbide.

3.7 CERAMIC MATRIX COMPOSITES (CMC)

Ceramic matrix composites have ceramic matrix such as alumina, alumina silicate reinforced by silicon carbide. The advantages of CMC include high strength, hardness, high service temperature limits for ceramics, chemical inertness and low density. Naturally resistant to high temperature, ceramic materials have a tendency to become brittle and to fracture.

3.8 POLYMER MATRIX COMPOSITES (PMCs)

PMCs consist of high strength particles or short/ continuous fibers which are held together by a common organic matrix (polymer). The composite is designed so that the mechanical loads to which the structure is subjected in service are supported by the

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particle or fiber reinforcement. PMCs are often divided into two categories: reinforced plastics and so-called "advanced composites.

Table 2: Chemical compositions of glass fibers in wt%.

Type	(SiO_2)	(Al_2O_3)	TiO_2	B_2O_3	(CaO)	(MgO)	Na_2O	K_2O	Fe_2O_3
E-glass	55.0	14.0	0.2	7.0	22.0	1.0	0.5	0.3	–
C-glass	64.6	4.1	–	5.0	13.4	3.3	9.6	0.5	–
S-glass	65.0	25.0	–	–	–	10.0	–	–	–
A-glass	67.5	3.5	–	1.5	6.5	4.5	13.5	3.0	–
D-glass	74.0	–	–	22.5	–	–	1.5	2.0	–
R-glass	60.0	24.0	–	–	9.0	6.0	0.5	0.1	–
EGR-glass	61.0	13.0	–	–	22.0	3.0	–	0.5	–
Basalt	52.0	17.2	1.0	–	8.6	5.2	5.0	1.0	5.0

Table 3: Physical and mechanical properties of glass fiber.

Fiber	Density (g/cm^3)	Tensile strength GPa	Young's modulus (GPa)	Elongation (%)	Coefficient of thermal expansion ($10^{-7}/°C$)	Poisson's ratio	Refractive index
E-glass	2.58	3.445	72.3	4.8	54	0.2	1.558
C-glass	2.52	3.310	68.9	4.8	63	–	1.533
S_2-glass	2.46	4.890	86.9	5.7	16	0.22	1.521
A-glass	2.44	3.310	68.9	4.8	73	–	1.538
D-glass	2.11–2.14	2.415	51.7	4.6	25	–	1.465
R-glass	2.54	4.135	85.5	4.8	33	–	1.546
EGR-glass	2.72	3.445	80.3	4.8	59	–	1.579
AR glass	2.70	3.241	73.1	4.4	65	–	1.562

4 METHODS OF LAMINATE PREPARATION

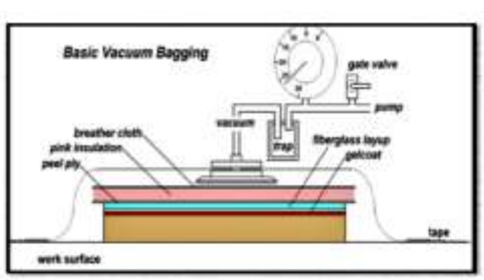
4.1 Hand Lay-Up Method

The simplest manufacturing technique adopted is laying down unidirectional glass roving over a polished mould surface previously treated with a releasing agent: after this, a liquid thermosetting resin is worked into the reinforcement by hand with a brush or roller. The process is repeated a number of times equal to the number of layers required for the final composite. Epoxy resins are most commonly used with glass fibers because of their good strength properties. Resin and curing agents are pre-mixed and normally designed to cross-link and harden at room temperature.

4.2 Vacuum Bagging Method

Also known as vacuum moulding, it requires a pump that will make use of atmospheric pressure to consolidate the material while curing by applying vacuum to the mould cavity. Usually the fibers are placed on a single mould surface and covered by a flexible membrane, sealed around the edges of the mould. The space between the mould and the membrane is then evacuated with a pump and the vacuum retained until the resin has cured. Figure shows an example of vacuum bagging as given by Kornmann et al (3005) where several layers of glass fabric were placed intercalated with epoxy resin.

4.1 **Fig : Vacuum Bagging Technique**



5. METHODOLOGY

5.1 Composite Specimen Preparation

The hand lay-up is one of the oldest, simplest and most commonly used methods for composite parts' construction. The specimen is fabricated in layer stacking, and each layer is oriented to achieve the maximum utilization of its properties. Layers of different materials can be combined to further enhance the overall performance of the laminated composite samples. Resins are impregnated by hand into fibers, which are in the form of woven, knitted, stitched or bonded fabrics. This is usually accomplished by rollers or brushes, with an increasing use of nip-roller type impregnators for forcing the resin into the fabrics, by means of rotating rollers. Then the composite laminates are allowed to cure under normal atmospheric conditions and dried under the hot sun for over 34 hours.

The composite samples used for the present investigation consist of five layers, and fabricated by the hand layup method. In the five layers, the glass fiber layers are mounted on the top, middle and bottom of the specimen. Add 10% catalyst by weight with resin for quick setting, immediate mixing, and reduce the heat generated due to exothermic reaction.Then the resin is applied over the glass fiber mat and the resin is evenly distributed on the entire surface by using a roller. The resin is allowed 10-30 minutes for getting completely mixed; after that, the second layer of the specimen. The air gaps formed between the layers during processing are gently squeezed out.


Fig 5.1 Cutting of Glass fiber layer Fig 5.2 Mould preparation

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Fig 5.3 Resin distribution Fig 5.4 Fabricated composite laminates

5.3 Fabrication Of Polymer Matrix Composite

The Glass fiber/Epoxy based hybrid composites are developed using hand layup process by varying both the reinforcements by layers of glass fiber of Epoxy matrix. The weight fraction of fibers and epoxy matrix materials were determined by considering the density, specific gravity and mass. Initially, the fabrication of the composite was done at room temperature by hand lay-up technique. The required ingredients of resin and hardener were mixed thoroughly in a basin and the mixture is subsequently stirred constantly.

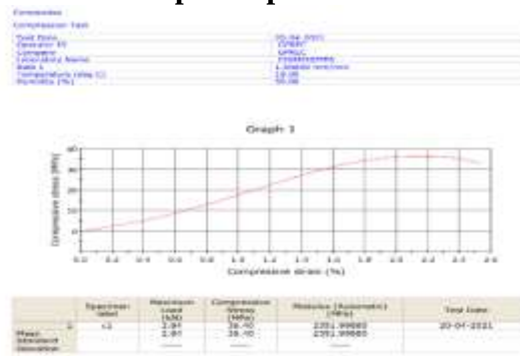
A mould was prepared on par with ASTM dimensions, and it was coated with a mould releasing agent (poly-vinyl-alcohol) for easy removal of casting. Predetermined dimensions of 300 x 300 mm glass woven fiber were cut with appropriate scissors and made sure to ensure flat surfaces of mats.


Fig5.4:I Layer Composite Fig 5.5: II Layer Composite

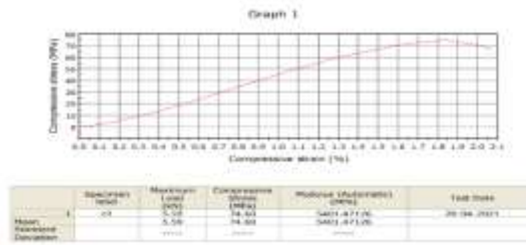
5.4Applications

- **Electronics:** GRP has been widely used for circuit board manufacture (PCB's), TVs, radios, computers, cell phones, electrical motor covers etc.
- **Home and furniture:** Roof sheets, bathtub furniture, windows, sun shade, show racks, book racks, tea tables, spa tubs etc. .

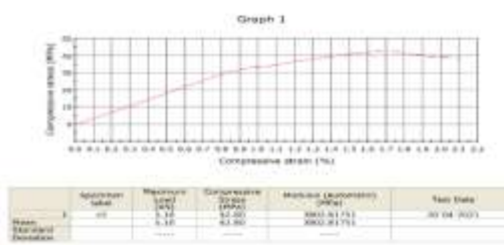
6. Results Of Frp Composites



6.1 Testing Result for C1 (epoxy resin) specimen



6.2 Testing Result for C2 (epoxy resin with single layer glass fiber) specimen



6.3 Testing Result for C3 (epoxy resin with double layer glass fiber) specimen

CONCLUSION

The experimental investigations used for the analysis of mechanical behaviour of bi-woven glass fiber reinforced polymer laminates successfully fabricated by simple hand lay- up technique leads to the following conclusions. Experimental evaluation of mechanical properties like tensile, compressive, impact & flexural strength of hybrid composites as per ASTM standards has been successfully completed. The tensile properties have been studied and the breaking load has been measured. The inclusion of glass fiber mat reinforced polymeric composite significantly enhanced the ultimate tensile strength, yield strength and peak load of the composite. Ultimate tensile strength and flexural strength of the fiber glass polyester composite increased with increase in the fiber glass Volume fraction of fiber weight fractions. The Young's modulus of elasticity

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of the composite increased with the fiber glass Volume fraction. Young's modulus of specimens increases with increase in laminates irrespective of its orientation. Flexural strength and tensile strength were found to be improved layer to layer, however, flexural modulus and tensile modulus increased linearly from layer to layer.

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