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Fabrication of glass-polymer composite laminate with different angle ply orientation

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Abstract
This work involves Fabrication of E-glass general polyester and Epoxy composite laminate with Different Angle Ply Orientation. Laminated Composite materials have characteristics of high modulus/weight and strength/weight ratios, excellent fatigue properties, and non-corroding behaviour. These advantages encourage the extensive application of composite materials, for example, in wind turbine blades, boat hulls, automobiles, water tanks, roofing, pipes and cladding, and aerospace. The understanding of the mechanical behaviour of composite materials is essential for their design and application. Although composite materials are often heterogeneous, they are presumed homogeneous from the viewpoint of macro mechanics and only the averaged apparent mechanical properties are considered. The most common method to determine these constants is static testing. In this work ten types of composite laminate specimens with different stacking sequences, i.e., ($\pm 0^0$, $\pm 10^0$, $\pm 30^0$, $\pm 40^0$, $\pm 45^0$, $\pm 55^0$, $\pm 65^0$, $\pm 75^0$, and $\pm 90^0$) are fabricated and specimens are prepared in the laboratory using compression mould technique E- glass as fibre & with Polyester resin and Epoxy as an adhesive. The specimens are prepared for testing as per ASTM standards to estimate the tensile modulus.

Keywords: component, compression moulding, degree of orientation, E-glass, epoxy, MEKP, stacking sequence, tensile property

1. Introduction
Composite materials can be defined as materials composed of two or more distinctly identifiable constituents in the case of natural composites like timber, organic materials, soil aggregates, minerals and rock. Fibres or particles embedded in matrix of another material would be the best example for modern day composites.

2. Types of Composites
Wherever Composite materials are commonly classified at following two distinct levels. The first level of classification is usually made with respect to the matrix constituent. The major composite classes include Organic Matrix Composites (OMCs), Metal Matrix Composites (MMCs) and Ceramic Matrix Composites (CMCs). The term organic matrix composite is generally assumed to include two classes of composites, namely Polymer Matrix Composites (PMCs) and carbon matrix composites commonly referred to as carbon-carbon composites. The second level of classification refers to their enforcement form-fibre reinforced composites, laminar composites and particulate composites. Fibre reinforced composites can be further divided into those containing discontinuous or continuous fibres.

1.1 Types of composite materials
The commonly accepted types of composite materials are:
a. Fibrous composites
b. Laminated composites
c. Particulate composites

1.1.1 Fibrous Composites
Long fibers in various forms are inherently much stiffer and stronger than the same materials in the bulk form. The fibers are the principal reinforcing or load-carrying agent. They are typically strong and stiff. The geometry of fibers were somehow crucial to evaluate their strength and must be considered in structural applications.

1.1.2 Laminated Composites
Laminated composites consist of layers of at least two different materials that are bounded together. The properties that can be emphasized are strength, stiffness, low weight, corrosion resistance, wear resistance, beauty, thermal insulation, acoustical insulation, etc. examples of laminated composites are bimetals, clad metals, laminated glass and plastic based laminated & laminated fibrous composites.

1.1.3 Particulate Composites
Particulate composites consist of particles of one or more material suspended in a matrix of another material. The particles can be either metallic or nonmetallic. Common combinations of these possibilities are nonmetallic in nonmetallic composites, metallic in metallic composites and nonmetallic in metallic composites.

1.2 Classification of composites
Composite materials can be classified in different ways as shown in Figure.1. Classification is based on the geometry of are preventative unit of reinforcement which is responsible for the mechanical properties and high performance of the composites. Composite consists of two major ingredients *viz*: reinforcing fibers (dispersed phase) responsible for stress resistance and matrix materials (continuous phase) responsible for stress propagation.

1.3 Fiber reinforced composites (FRP)

Fiber reinforced composites are composed of fibers and a matrix. Fibers are the reinforcement and the main source of strength while the matrix 'glues' all the fibers together in shape and transfers stresses between the reinforcing fibers. Sometimes, fillers or modifiers might be added to smooth manufacturing process, impart special properties, and/or reduce product cost.

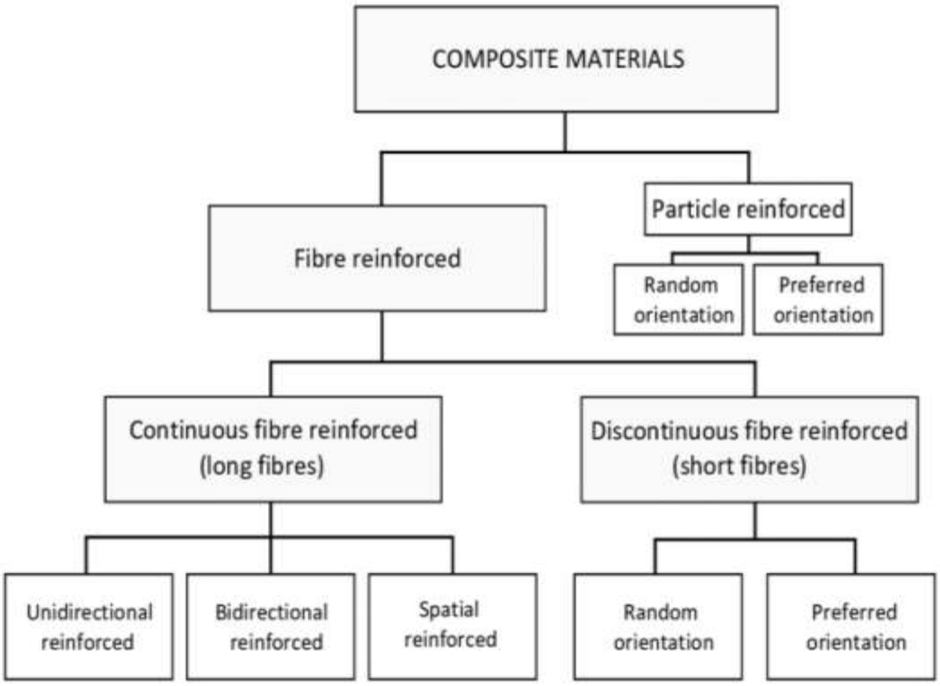

Fig 1

3. Fibres

Fibre is a rope or string used as a component of composite materials, or matted into sheets to make products such as paper or felt. Fibres are often used in the manufacture of other materials. The strongest engineering materials are generally made as fibre for example carbon fibre and Ultra-high-molecular-weight polyethylene.

a. Natural Fibres

Natural fibres' include those produced by plants, animals, and geological processes. They are biodegradable over time. These are generally based on arrangements of cellulose often with lignin. Plant fibres are employed in the manufacture of paper and textile (cloth), and dietary fibre is an important component of human nutrition. Animal fibres consist largely of particular proteins. Instances are silkworm silk, spidersilk, sinew, catgut, wool, seasilk and hair such as cashmere wool, mohair and angora, fur such as sheepskin, rabbit, mink, fox, beaver, etc. Asbestos is the only naturally occurring long mineral fiber. Six minerals have been classified as "asbestos" including chrysotile of the serpentine class and those belonging to the amphibole class: amosite, crocidolite, tremolite, anthopyllite and actinolite. Short, fiber-like minerals include wollastonite and palygorskite.

b. Man Made fibres

Man-made fibres or chemical fibres are fibres whose chemical composition, structure, and properties are significantly modified during the manufacturing process. Man-made fibres consist of regenerated fibres and synthetic fibres. Cellulose fibres are a subset of man-made fibres, regenerated from natural cellulose. The cellulose comes from various sources. Modal is made from beech trees, bamboo fibre is a cellulose fibre made from bamboo, seacell is made from seaweed, etc. Semi-synthetic fibres are made from raw materials with naturally long-chain polymer structure and are only modified and partially degraded by chemical processes, in contrast to completely synthetic fibres such as nylon (polyamide) or dacron (polyester), which the chemist synthesizes from low-molecular weight compounds by polymerization (chain-building) reactions. The first semi-synthetic fibre is rayon. Synthetic come entirely from synthetic materials such as petrochemicals, unlike those man-made fibres derived from such natural substances as cellulose or protein. Metallic fibres can be drawn from ductile metals such as copper, gold or silver and extruded or deposited from more brittle ones, such as nickel, aluminum or iron. See also Stainless steel fibres. Carbon fibres are often based on oxydized and via pyrolysis carbonized polymers like PAN, but the end product is almost pure carbon. Silicon carbide fibres, where the basic polymers are not hydrocarbons but polymers, where about 50% of the carbon atoms are replaced by silicon atoms, so-called poly-carbo-silanes. The pyrolysis yields an amorphous silicon carbide, including mostly other elements like oxygen, titanium, or aluminium, but with mechanical properties very similar to those of carbon fibres. Fiberglas, made from specific glass, and optical fibre, made from purified natural quartz, are also man-made fibres that come from natural raw materials, silica fibre, made from sodium silicate (water glass) and basalt fibre made from melted basalt. Mineral fibres can be particularly strong because they are formed with a low number of surface defects, asbestos is a common one. Polymer fibres are a subset of man-made fibres, which are based on synthetic chemicals (often from petrochemical sources) rather than arising from natural materials by a purely physical process. Microfibers in textiles refer to sub-denier fibre (such as polyester drawn to 0.5 dn). Denier and Detex are two measurements of fibre yield based on weight and length. If the fibre density is known you also have a fibre diameter, otherwise it is simpler to measure diameters in micrometers. Microfibers in technical fibres refer to ultrafine fibres (glass or meltblown thermoplastics) often used in filtration.

4. Manufacturing of Fibres

Most synthetic and cellulosic manufactured fibres are created by "extrusion" — forcing a thick, viscous liquid (about the consistency of cold honey) through the tiny holes of a device called a spinneret to form continuous filaments of semi-solid polymer. In their initial state, the fibre-forming polymers are solids and therefore must be first converted into a fluid state for extrusion. This is usually achieved by melting, if the polymers are thermoplastic synthetics (i.e., they soften and melt when heated), or by dissolving them in a suitable solvent if they are non-thermoplastic cellulosic's. If they cannot be dissolved or melted directly, they must be chemically treated to form soluble or thermoplastic derivatives. Recent technologies have been developed for some specialty fibres made of polymers that do not melt, dissolve, or form appropriate derivatives. For these materials, the small fluid molecules are mixed and reacted to form the otherwise intractable polymers during the extrusion process.

5. Glass Fibers

Glass fiber is formed when thin strands of silica-based or other formulation glass are extruded into many fibers with small diameters suitable for textile processing. The technique of heating and drawing glass into fine fibers has been known for millennia. However, the use of these fibers for textile applications is more recent. Until this time, all glass fiber had been manufactured as staple i.e. clusters of short lengths of fiber.

The types of glass fiber most commonly used are mainly

- E-glass (alumina-borosilicate glass with less than 1% w/w alkali oxides, mainly used for glass-reinforced plastics)
- A-glass (alkali-lime glass with little or no boron oxide),
- E-CR-glass (alumina-lime silicate with less than 1% w/w alkali oxides, has high acid resistance),
- C-glass (alkali-lime glass with high boron oxide content, used for example for glass staple fibers),
- D-glass (borosilicate glass with low dielectric constant),
- R-glass (alumina silicate glass without MgO and CaO with high mechanical requirements),
- S-glass (alumina silicate glass without CaO but with high MgO content with high tensile strength).

6. Resin

Resin in the most specific use of the term is a hydrocarbon secretion of many plants, particularly coniferous trees. Resins are valued for their chemical properties and associated uses, such as the production of varnishes, adhesives and food glazing agents. They are also prized as an important source of raw materials for organic synthesis, and as constituents of incense and perfume. Plant resins have a very long history that was documented in ancient Greece by Theophrastus, in ancient Rome by Pliny the Elder, and especially in the resins known as frankincense and myrrh, prized in ancient Egypt. These were highly prized substances, and required as incense in some religious rites. Amber is a hard fossilized resin from ancient trees.

7. Preparation of Composite Laminate by Compression Moulding Technique

Composite laminate is prepared using compression moulding technique. Here Four plies of E-glass fibre are taken in a symmetric manner i.e. ($+0^0$, -0^0, -0^0, $+0^0$) one over the other and epoxy resin is used as an adhesive. The size of the mould taken is 30 × 30 cm. Initially the glass fiber is to be cut in required shape of the size 30 × 30 cms of required orientation. Two plies of positive orientation (anti-clockwise) and other two in negative orientation (clockwise) are to be prepared. The fig.5.1 shows the step 1 procedure. A thin plastic sheet is used at the top and bottom of the mould in order get good surface finish for the laminate.

The mould has to be cleaned well after that PVA (Poly Vinyl Acetate) is applied in order to avoid sticking of the laminate to the mould after curing of the laminate. As explained a thin plastic sheet is placed at the bottom of mould. Then a ply of positive orientation is taken is placed over the sheet. Sufficient amount of resin which is prepared beforehand (hardener of quantity 10% of the resin is to be mixed with the resin and get stirred well) is poured over the ply.

The resin poured in to the mould uniformly and it is rolled in order to get the required bonding using a rolling device. Enough care should be taken to avoid the air bubbles formed during rolling. Then on this ply, other ply of negative orientation (clock wise) is placed, the same procedure is followed. After this, other two plies are placed and rolling is done.

Fig 2

Fig 3

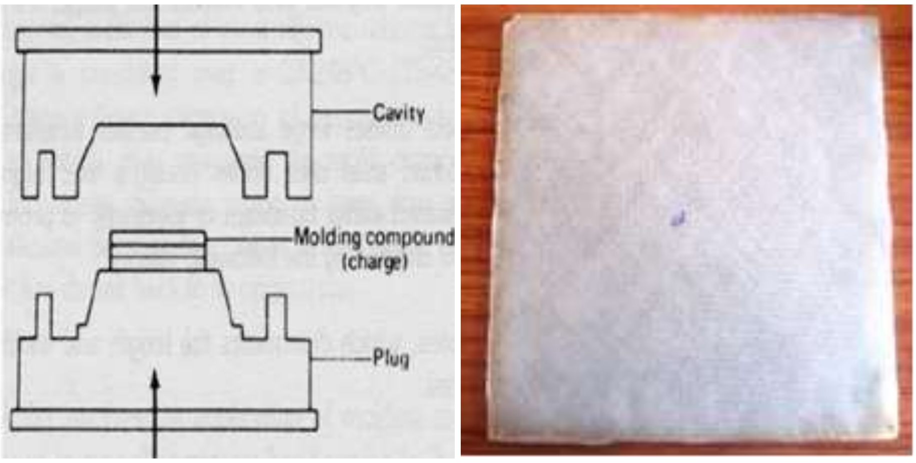

Fig 4

After the rolling of all plies, the covering sheet (plastic sheet) is placed and the mould is closed with the upper plate. The compression is applied on the fiber- resin mixture by tightening the two mould plates uniformly. Enough care should be taken to provide uniform pressure on the laminate while fixing plates. After enough curing time (7-10 hrs) the laminate is removed from the mould plates carefully. Thus laminates are prepared.

8. Preparation of Specimen for the Tensile Test

After preparing the laminate, in order to conduct the tensile test, specimen is prepared using ASTM standards D3039 which is showed in below fig.. The specimen is prepared in dog-bone shape which has a gauge length of 150 mm (can take length 100-150 mm).

Fig 5

9. Result and Future Scope

The laminates for different angle ply orientation for ($\pm 0^0$, $\pm 10^0$, $\pm 30^0$, $\pm 40^0$, $\pm 45^0$, $\pm 55^0$, $\pm 65^0$, $\pm$ 75^0, and $\pm 90^0$) is prepared for further investigation to calculate inter lamina shear strength and fatigue failure behavior of composite laminates under cyclic loading for critical applications like wind turbine blades and aero plane wings.

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