ANALYSIS OF ANGEL PLY LAMINATED COMPOSITE AND VALIDATION

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Abstract— In this paper, the specimens are fabricated using carbon fiber, E-Glass fiber, epoxy resin and Hardener HY104 with the help of hand lay-up technique. The effect of fiber orientation and thickness of laminates has been investigated and experimentation was performed to determine property data for material specification. Specimens are cut as per ASTM standards. Furthermore, failure mode and strength characteristics of composites specimens with different fiber orientations will be studied. For all geometrics of specimen, the ultimate strength, breaking stress and elongation will be recorded. Analysis was tested by using ANSYS software.

This research indicates that the mechanical properties are mainly dependent on fiber orientation of laminates and thickness of laminated polymer composites.

Index Terms— Composite materials, Carbon fiber, E-Glass fiber, Epoxy resin, Hardener HY104, Fiber orientation and thickness of laminates.

I. INTRODUCTION

Composite materials are manufactured from two or more materials to take advantage of desirable characteristics of the components. A composite material, in mechanics sense, is a structure with the ingredients as element transferring forces to adjacent members. The advance in design and application of composites has accelerated in the past decade especially in the aeronautics, defence, and space industries. Commercial applications are also increasing as products needing challenging materials properties are increasing in demand.

The majority of composite materials use two constituents: a binder or matrix and reinforcement. The reinforcement is stronger and stiffer, forming a sort of backbone, while the matrix keeps the reinforcement in a set place. The binder also protects the reinforcement, which may be brittle or breakable, as in the case of the long glass fibers used in conjunction with plastics to make fibre glass. Generally, composite materials have excellent compressibility combined with good tensile strength, making them versatile in a wide range of situations. In this project the specimens are fabricated using carbon and glass fibre cloth with epoxy resin and hardener HY 951 with the help of vacuum hand-layup technique. Tensile specimens as per ASTM Standards will be prepared with different hole diameters. Furthermore, failure mode and strength characteristics of composite specimens consisting of central holes of different diameters will be studied. For all geometries of the specimens, the ultimate strength, breaking stress and elongation will be recorded.

A. Carbon Reinforced Fiber

Carbon fiber (carbon fibre), CRF is a material consisting of extremely thin fibers about 0.005–0.010 mm in diameter and composed mostly of carbon atoms. The carbon atoms are bonded together in microscopic crystals that are more or less aligned parallel to the long axis of the fiber. Carbon fiber-reinforced plastic (CFRP or CRP), is a very strong, light, and expensive composite material or fiber-reinforced polymer. Similar to fiberglass (glass reinforced polymer), the composite material is commonly referred to by the name of its reinforcing fibers (carbon fiber). The polymer is most often epoxy, but other polymers, such as polyester, vinyl ester or nylon. The crystal alignment makes the fiber very strong for its size. Several thousand carbon fibers are twisted together to form a yarn, which may be used by itself or woven into a fabric.

Carbon fiber has many different weave patterns and can be combined with a plastic resin and wound or moulded to form composite materials such as carbon fiber reinforced plastic (also referenced as carbon fiber) to provide a high strength-to-weight ratio material. The density of carbon fiber is also considerably lower than the density of steel, making it ideal for applications requiring low weight. The properties of carbon fiber such as high tensile strength, low weight, and low thermal expansion make it very popular in aerospace, civil engineering, military, and motorsports, along with other competition sports.

However, it is relatively expensive when compared to similar materials such as fiberglass or plastic. Carbon fiber is very strong when stretched or bent, but weak when compressed or exposed to high shock (eg. a carbon fiber bar is extremely difficult to bend, but will crack easily if hit with a hammer).It has many applications in aerospace and automotive fields, as well as in sailboats, and notably in modern bicycles and motorcycles, where its high strength-to-weight ratio is of importance. Improved manufacturing techniques are reducing the costs and time to manufacture, making it increasingly common in small consumer goods as well, such as laptops, tripods, fishing rods, paintball equipment, archery equipment, racquet frames, stringed instrument bodies, classical guitar strings, drum shells, golf clubs, and pool/billiards/snooker cues.

B. Glass-Reinforced Plastic

Glass-reinforced plastic or GRP is a composite material made of a plastic matrix reinforced by fine fibers made of glass. It is also known as GFK (for Glass Fiber komposite), or simply by the name of the reinforcing fibers themselves: fiberglass.GRP is a lightweight, strong material with very many uses, including boats, automobiles, water tanks, roofing, pipes and cladding.The plastic matrix may be a thermosetting plastic (most often polyester or vinyl ester), epoxy or thermoplastic.The manufacturing process for GRP fiber glass uses large furnaces to gradually melt the sand/chemical mix to liquid form, and then extrude it through bundles of very small orifices (typically 17-25 micrometers in diameter for E-Glass, 9 micrometers for S-glass).

These filaments are then sized with a chemical solution. The individual filaments are now bundled together in large numbers to provide a roving. The diameter of the filaments, as well as the number of filaments in the roving determines its weight. This is typically expressed in yield-yards per pound (how many yards of fiber in one pound of material, thus a smaller number means a heavier roving, example of standard yields are 225yield, 450yield, 675yield) or in tex-grams per km (how many grams 1 km of roving weighs, this is inverted from yield, thus a smaller number means a lighter roving, examples of standard tex are 750tex, 1100tex, 2200tex).An individual structural glass fiber is both stiff and strong in tension and compression—that is, along its axis. Although it might be assumed that the fiber is weak in compression, it is actually only the long aspect ratio of the fiber which makes it seem so; i.e., because a typical fiber is long and narrow, it buckles easily.

On the other hand, the glass fiber is unstiff and unstrong in shear—that is, across its axis. Therefore if a collection of fibers can be arranged permanently in a preferred direction within a material, and if the fibers can be prevented from buckling in compression, then that material will become preferentially strong in that direction.Furthermore, by laying multiple layers of fiber on top of one another, with each layer oriented in various preferred directions, the stiffness and strength properties of the overall material can be controlled in an efficient manner.

In the case of glass-reinforced plastic, it is the plastic matrix which permanently constrains the structural glass fibers to directions chosen by the designer. With chopped strand mat, this directionality is essentially an entire two dimensional plane; with woven fabrics or unidirectional layers, directionality of stiffness and strength can be more precisely controlled within the plane.A glass-reinforced plastic component is typically of a thin "shell" construction, sometimes filled on the inside with structural foam, as in the case of surfboards. The component may be of nearly arbitrary shape, limited only by the complexity and tolerances of the mold used for manufacturing the shell.

These rovings are then either used directly in a composite application such as pultrusion, filament wounding (pipe), gun roving (automated gun chops the glass into small lengths and drops it into a jet of resin, projected onto the surface of a mold), or used in an intermediary step, to manufacture fabrics such as chopped strand mat (CSM) (made of randomly oriented small cut lengths of fiber all bonded together), woven fabrics, knit fabrics or uni-directional fabrics.

Process: Resin is mixed with a catalyst (e.g. butanox LA) or hardener if working with epoxy, otherwise it will not cure (harden) for days/ weeks. Next, the mould is wetted out with the mixture. The sheets of fiber glass are placed over the mould and rolled down into the mould using steel rollers. The material must be securely attached to the mould; air must not be trapped in between the fiber glass and the mould. Additional resin is applied and possibly additional sheets of fiber glass.

II Methodology For Specimen Preparation

- Fabricate hybrid laminated composite specimens with E-Glass and Carbon fiber combination as per ASTM standards.
- Evaluate the mechanical properties (tension, flexural and compression) of the above composite.
- Determine the mechanical parameters for the specimens under different orientation of the fiber.
- Assess the post static test results and evaluate the extent of damage of hybrid composite specimens with the carbon fiber specimens.
- Discuss the results obtained from the experimentation and analysis by using ANSYS and finally to conclude the performance of composites about its mechanical characteristics for various applications.

A. Preparation of Specimen

- Carbon fiber & Glass fiber material consisting of extremely thin fibers about 0.005–0.010 mm in diameter and composed mostly of carbon atoms.
- The process by which most carbon fiber-reinforced polymer is made varies, depending on the piece being created, the finish (outside gloss) required, and how many of this particular piece are going to be produced.
- Glass-reinforced plastic or GRP is a composite material made of a plastic matrix reinforced by fine fibers made of glass
- The bi-woven clothes are available in the standard form of 0.37mm thickness.
- Bi-Woven cloths are cut to the required size & shape.
- These cloths are stacked layer by layer of about 5 layers to attain the thickness of 2mm as per the ASTM Standard Specimen.

- Bonding agent (epoxy resin and hardener) is applied to create bonding between 5 layers of sheet, in the ratio of 2:1.

The process of polymerization is called "curing", and can be controlled through temperature and choice of resin and hardener 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. Process of vacuuming will be done to remove air traps exist between the layers. Vacuuming & Room curing to be done about 3hrs. After curing process the materials cut to the required size & Shape as per ASTM Standard.

Fig-1 Specimens as per ASTM Standards

B. Evaluate the mechanical properties

Tensile test: Consider the typical tensile specimen shown in Fig 2. It has enlarged ends or shoulders for gripping. The important part of the specimen is the gage section.

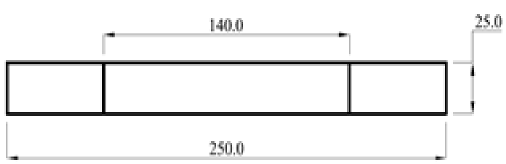

Fig-2 Tensile Specimen Dimensions as per ASTM D-3039

The cross-sectional area of the gage section is reduced relative to that of the remainder of the Specimen so that deformation and failure will be localized in this region. The gauge length is the region over which measurements are made and is centered within the reduced section. The distances between the ends of the gage section and the shoulders should be great enough so that the larger ends do not constrain deformation within the gage section, and the gage length should be great relative to its diameter. Otherwise, the stress state will be more complex than simple tension.

The most important concern in the selection of a gripping method is to ensure that the specimen can be held at the maximum load without slippage or failure in the grip section Bending should be minimized.

Flexural Testing: Flexural strength is the ability of the material to withstand bending forces applied Perpendicular to its longitudinal axis. Sometime it is referred as cross breaking strength where maximum stress developed when a bar-shaped test piece, acting as a simple beam, is subjected to a bending force perpendicular to the bar. There are two methods that cover the determination of flexural properties of material: three-point loading system and four point loading system. As described in ASTM D7264, three-point loading system applied on a supported beam was utilized. Flexural test is important for designer as well as manufacturer in the form of a beam.

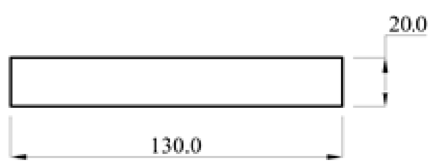

Fig-3 Specimen Dimensions as per ASTM D-3039

Compression test: Compression testing is also a fundamental materials science test in which a sample is subjected to uniaxial compressive load. The results from the test are commonly used to select a material for an application, for quality control and to predict how a material will react under other types of forces.

The most common testing machine used for compression test is a Universal Testing Machine (UTM).

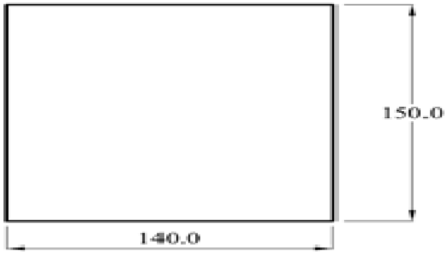

Fig-4 Specimen Dimensions as per ASTM D-3039

III EXPERIMENTAL RESULTS AND FEA RESULTS

A. TENSILE TEST RESULTS

TABLE-1 TENSILE TEST EXPERIMENTAL RESULTS AND FEA RESULTS

Sample Thickness (mm)	Fibre orientation	Experimental Stress (Mpa)	FEA Stress (Mpa)	Experimental displacement (mm)	FEA displacement (mm)
2	90º	219.2	227.03	7.9	9.48
2	60º	53.6	55.51	9.45	11.32
2	45º	43.6	45.14	13.4	13.31

B. FLEXURAL TEST RESULTS

TABLE-2 FLEXURAL TEST EXPERIMENTAL RESULTS AND FEA RESULTS

Sample Thickness (mm)	Fibre orientation	Experimental Stress (Mpa)	FEA Stress (Mpa)	Experimental displacement (mm)	FEA displacement (mm)
2	90º	288.82	325.32	10.7	10.896
2	60º	157.59	158.27	18.2	15.94
2	45º	118.15	123.28	24.1	19.13

C. COMPRESSION TEST *RESULTS*

TABLE-3 COMPRESSION TEST EXPERIMENTAL RESULTS AND FEA RESULTS

Sample Thickness (mm)	Fibre orientation	Experimental Stress (Mpa)	FEA Stress (Mpa)	Experimental displacement (mm)	FEA displacement (mm)
2	90º	2.83	2.344	34	35.78
2	60º	0.50	1.0049	43.8	47.94
2	45º	0.357	0.2989	80.4	79.9

IV CONCLUSION

When composite materials are designed, the reinforcements are always oriented in the load direction. However if the load direction is variable and not parallel to the fibres it becomes more important to investigate the laminate mechanical behaviour. To investigate the effect of fibre orientation, ±45^0, ±60 ^{0}and ±90^0 were selected under this study. Specimens with different fibre orientation Were Prepared under the same condition as discussed earlier. The experimental investigations used for the analysis of tensile, flexural and compression behaviour of carbon and E-glass fibre reinforced polymer laminates leads to following conclusion.

The experimental results shows that the tensile, flexural and compression strength is affected by the fibre orientation significantly summarized below;

- The tensile, flexural and compression strength is superior in case of 45^0 orientation.
- More load is required for fracture of laminates in case of 90^0 orientation.
- More elongation is observed in case of 45^{0}orientation.
- The elongation is minimal in case of 90^{0}orientation.
- Specimen sustain greater load in 90^{0}orientation as compared to other orientations.
- Young's modulus is more in case of 90^{0}orientation.
- Young's modulus of specimens is increases with decreases in thickness of the specimen.

REFERENCES

[1] Prashanth Banakar, H.K. Shivananda and H.B. Niranjan "Influence of Fibre Orientation and Thickness on Tensile Properties of Laminated Polymer Composites" Int. J. Pure Appl. Sci. Technol., 9(1) (2012), pp. 61-68.

[2] Keshavamurthy Y C , Dr. Nanjundaradhya N V , Dr. Ramesh S Sharma, Dr. R S Kulkarni "Investigation of Tensile Properties of Fibre Reinforced Angle Ply laminated composites" ISSN 2250-2459, Volume 2, Issue 4 April 2012.

[3] GuruRaja M. N, A. N. HariRao. "Hybrid Effects on Tensile Properties of Carbon/Glass Angle Ply Composites". Advances in Materials. Vol. 2, No. 3, 2013, pp. 36-41.

[4]. K.Vasantha Kumar1, Dr.P.Ram Reddy , Dr.D.V.Ravi Shankar " Effect of Angle Ply Orientation On Tensile Properties Of Bi Directional Woven Fabric Glass Epoxy Composite Laminate" International Journal of Computational Engineering Research Vol, 03 , Issue 2010.

[5] K. Kishor Kumar, P. Ramesh Babu and K. Raja Narender Reddy "Evaluation of Flexural and Tensile Properties of Short Kenaf Fibre Reinforced Green Composites". International Journal of Advanced Mechanical Engineering. ISSN 2250-3234 Volume 4, Number 4 (2014), pp. 371-380.

[6] Swanson SR. Introduction to design and analysis with advanced composite materials. Englewood Cliffs, NJ: Prentice Hall, 1997

[7] Yong X. Gan Effect of interface on mechanical properties of advanced composite materials J of Mol.sci.2009:5115-5134

[8] Marissen R. Flight simulation behaviour of aramid reinforced aluminium laminates. Eng Fract Mech 1984:19:261-77.

[9] Tensile properties and fatigue characteristics of hybrid composites with non-woven carbon tissue Jl. of fatigue 2007:397-405.

[10] ASM Data hand book: 195

[11] G. Kretsis, a review of the Tensile, Compressive, Flexural and shear properties of hybrid fibre reinforced plastics, Composites, Vol 18:1987

[12] J. Harding and L.M Welsh, A tensile testing technique for fibre-reinforced composites at impact rates of strain, J Master Sci 18:1983.

[13] J.Cho, Mechanical enhancement of carbon fibre/epoxy composites by graphite nanoplatelet reinforcement, S. Direct 2007:685-688