Research article Available online www.ijsrr.org ISSN: 2279–0543

International Journal of Scientific Research and Reviews

Influence of Angle Ply Orientation on the Inter laminar Shear Strength of Glass Fiber Reinforced Composites

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ABSTRACT

In engineering weight is a deciding factor for many designs. The desired quality of material for consideration is that it should have high strength to weight ratio. Composite material have high strength to weight ration when compared to traditional materials.A composite material consists of two or more materials of desired qualities stacked up in layers and bonded using matrix material. Thus the composite produced will have high strength to weight ration thanthe individual material that were used .This proposed work deals with the effect ofangle ply orientationon inter-laminar shear strength of glass fiber reinforced composites.For this angle orientations 30^0,45^0,60^0 and 75^0 were considered. Glass fiber composite specimens of 24x8x4dimensions as per ASTM D2344 standard were prepared using hand-lay up technique and tested for short beam shear test on universal testing machine. The experimental results were compared with FEM results from ANSYS and found that inter laminar shear strength is inversely proportional to ply angle of the fiber.

KEY WORDS — Composite Materials, ILSS,Short beam shear Unidirectional E-Glass Fiber

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I. INTRODUCTION

The use of composite materials has gained a widespread acceptance as an excellent way of obtaining stiffness, strong and light weighted structural element. Fibers or particles embedded in matrix of another material would be best example of modern day composite materials. Fibers of different compositions combine by using a reinforcing material will give a specific characteristic composite material. The structure of composite material is nothing but fillers bounded by matrix material which is also known as binder. The matrix binds the fibers together a bit like an adhesive and makes them more resistant to external damage, whereas the fibers make the matrix stiffer and stronger and help it resist cracks and fractures. Depending on the type of filler and matrix material composites are classified mainly into three groups namely particle reinforced, fiber reinforced and structural reinforced. The particle reinforced composite consists reinforcement in the form particles were as fiber reinforced consists fiber as reinforced material. The fiber reinforcement is further classified into discontinues fiber reinforcement and continues fiber reinforcement

Manufacturing of composite materials can be done either by thermo setting or thermoplastic process. This process are further divided in a broad way. Out of all the other process hand lay-up techniqueis oldest and most commonly used technique. In this technique fibers are arranged in layers with different ply orientation for maximum utilization of its properties. Bonding agent is impregnated between the layers by hand and the laminates are left to cure under standard atmospheric conditions for certain amount of time.Figure I represents an overview on hand-layup technique.

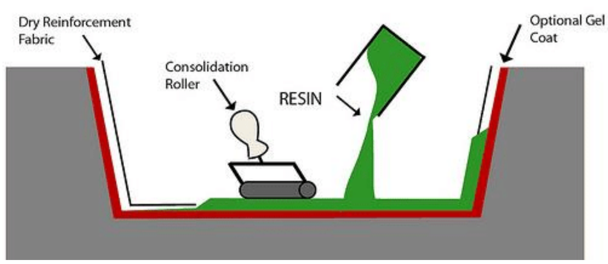

Figure 1. Hand-Layup Technique

II. PREPARATION OF TEST SPECIMEN

An alumina-calcium-borosilicate glass commonly known as E-glass fiber well known for its electrical resistant property and high ratio of surface area to weight ratio is selected as reinforcement material. General polyester resin is used as matrix material. To speed up the process Methyl Ethyl Ketone Peroxide [catalyst] and Cobalt Naphthenate[Hardener] were added to the resin.

Table 1.Specimen Composition

Material	Composition	Quantity
Matrix	General Polyester Resin	750 ml
Reinforcement	Unidirectional Glass Fiber Mat	4 layers
Catalyst	Methyl Ethyl Ketone Peroxide	5.5 ml
Hardener	Cobalt Naphthenate	7.5 ml

First of all a release agent in form of grease is applied on the mould surface to avoid the sticking of resin to the surface. Reinforcement in the form of unidirectional glass fiber mats are cut as per mould size (100 mm x 15mm) in 30^0ply angle orientation and placed in the mould. For unidirectional mat the glass to resin ratio should be between 2.3:1 and 1.8:1. The resin mixture as per specification is prepared and uniformly spread over the layer with the help of brush or roller. The roller is moved with mild pressure all over the layer to remove any air trapped as well as excess polymer from the mould. This process is repeated to form four layers of resin and glass fiber arranged in balanced symmetrical form. The mould is allowed for curing process under room temperature. After 24 hours the mould is opened and developed composite laminate is removed and further processed.

Above process is repeated for specimens of 45^0,60^0 and 75^0angle ply orientation stacked up in symmetrical manneri.e., +45/-45/-45/+45.The developed laminates were further processed by cutting them into 80mm x 8mm x 4mm as per ASME D2344 standard using CNC milling machine. Figure II represents test specimens prepared.

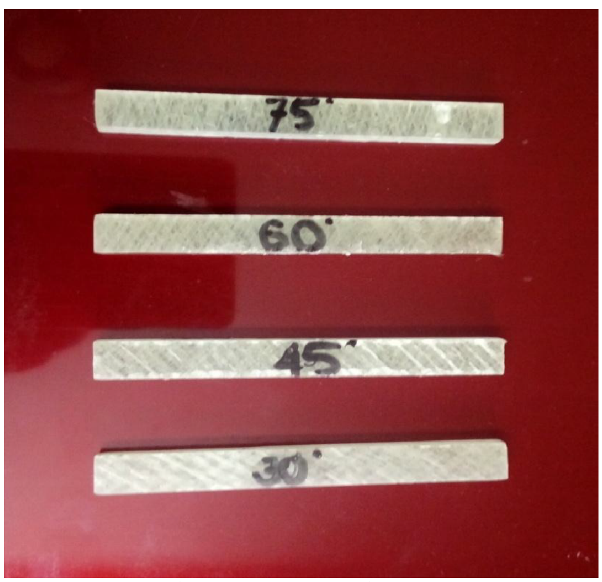

Figure 2. Test Specimens

III. TESTING

The mechanical testing of composite structure to obtain parameters such as strength and stiffness is often difficult and time consuming process. To simplify the testing, flat laminates are consider as test specimen. The results obtained from this tests can be related with varying degrees of simplicity and accuracy of any structural shape.

The common failure mode of beam loaded with three-point flexure is Inter-Laminar Shear at the neutral plane before the outer layers breaks due to tension and compression. The test specimen is placed on two 3.0 mm diameter cylindrical supports separated for a span length of 24 mm with care taken that the center of the specimen is at the center of span as per ASTM[3]. Loading supports were free to roll, allowing free lateral motion of the specimen. Load is applied in the center of specimen using 6.0 mm diameter steel dowel. The load is increased gradually until the beam is fractured and the fractured load is taken as a measure of the apparent shear strength of the material. Displacement was measured from the relative movement of the loading head through the use of integrated MTS linear displacement gauge.stress as the maximum shear stress does not occur at the center of the beam, despite these drawback this testis preferred as it was simple to perform, reproducible and the results can be used for qualitative evaluation of Inter-Laminar Shear Strength.

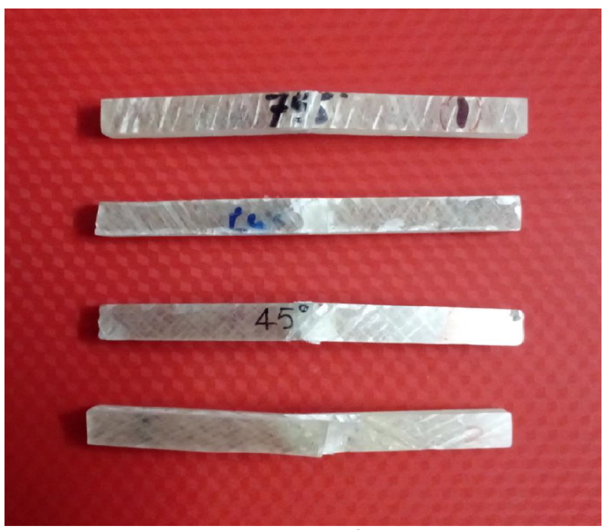

Figure 3. Specimens after Testing

IV. CALCULATIONS

With the results obtained from the short beam shear test, graph was plotted for load against deflection. The load at which the specimen gets fractured is considered as breaking load. By this the ILSS of the specimen is calculated using the below relation.

$$\tau = 0.75P_b/bt$$

Where P_b = Breaking load, b and t are width and thickness respectively.

Figure I, II, III& IV represents the ILSS variation for 30^0,45^0,60^0 and 75^0 respectively.

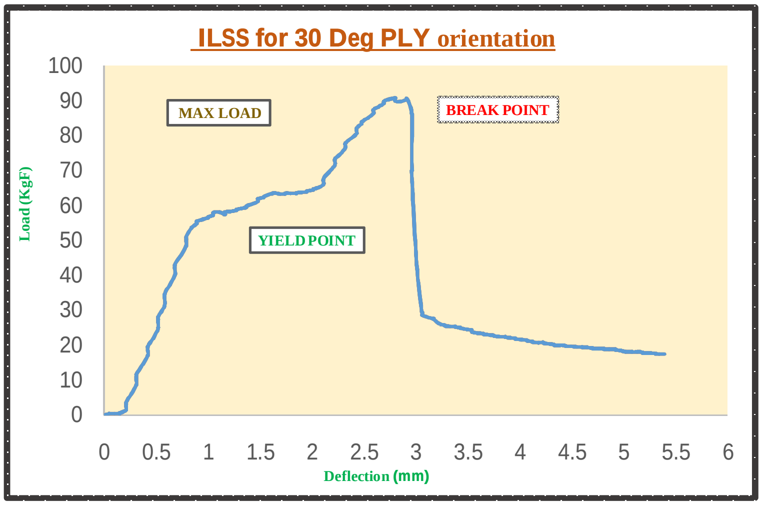

Figure 4. ILSS of 30^0 ($+30^0$/-30^0/-30^0/$+30^0$) By Short Beam Test

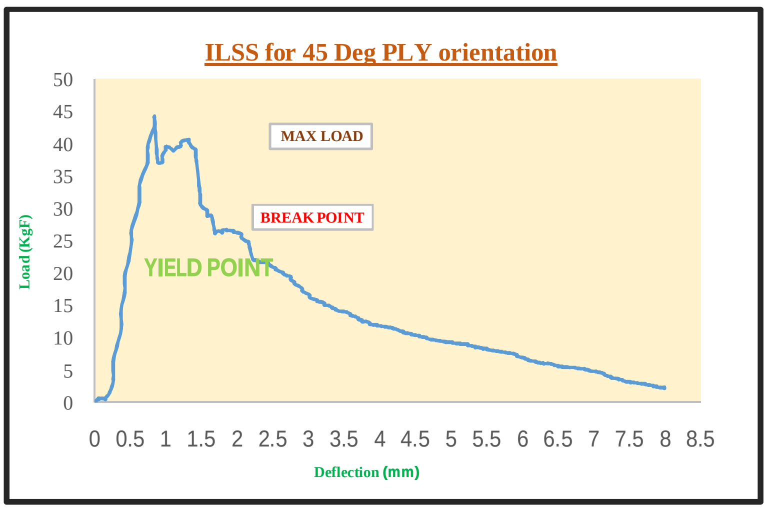

Figure 5.ILSS of 45^0 ($+45^0$/-45^0/-45^0/$+45^0$) By Short Beam Test

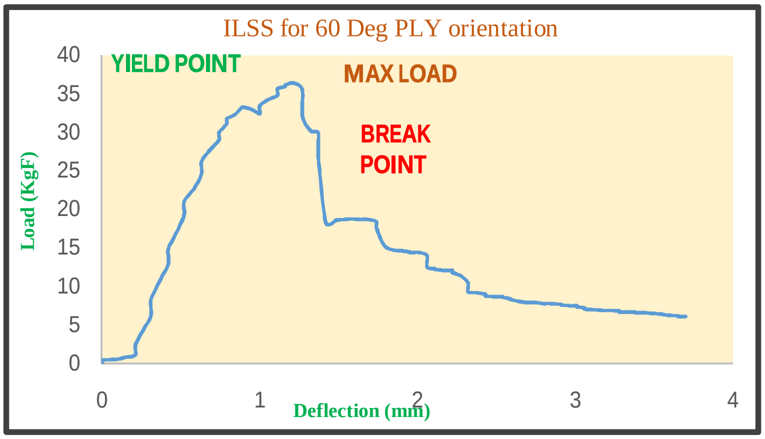

Figure 6. ILSS of 60^0 ($+60^0/-60^0/-60^0/+60^0$) By Short Beam Test

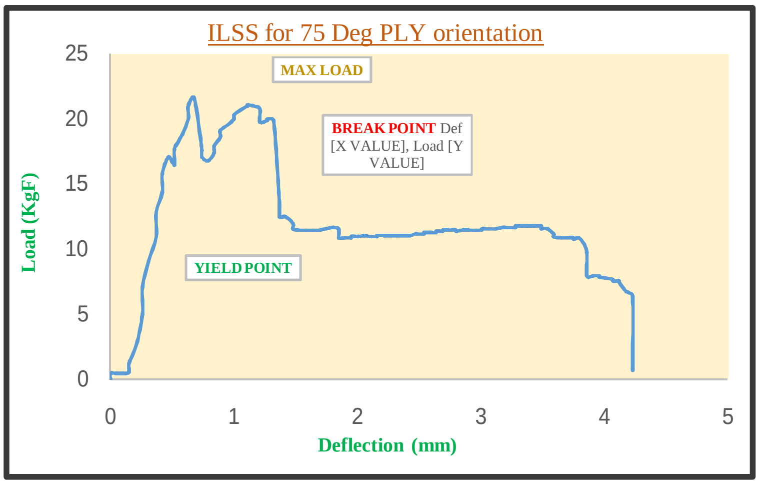

Figure 7. ILSS of 75^0 ($+75^0/-75^0/-75^0/+75^0$) By Short Beam Test

V. MODAL ANALYSIS

Structural modal analysis is carried out using ANSYS 14.5 on E-glass fiber and polyester resin as matrix material. In pre-processing phase the material properties, stacking sequence, modelling and meshing are created. In preprocessing the 3D model, 4 nodes and 181 shell elements were used. Specification for the specimen were taken as per ASTM D2344 standard i.e., 80mm X 8mm X 4mm.This model is solved in solution stage and analyzed for different parameters obtained from the results. The material properties of the specimen were calculated based on the assumption that the specimen is made up of 60% fiber and 40% polyester resin. The mesh refinement is based on the convergence studies. Figures represents modal analysis on different specimens.

VI. RESULTS AND DISCUSSIONS

With the results obtained from both experimental and modal analysis and following interpretations were made

- For 30^0 ply angle orientation the ILSS value obtained from experiment is 14.02 Mpa and 15.2 Mpa from modal analysis .The deviation between the two methods is 7.76%
- For 45^0 ply angle orientation the ILSS value obtained from experiment is 10.07 Mpa and 11.3 Mpa from modal analysis .The deviation between the two methods is 10.88%
- For 60^0 ply angle orientation the ILSS value obtained from experiment is 8.20 Mpa and 9.18 Mpa from modal analysis .The deviation between the two methods is 10.67%
- For 75^0 ply angle orientation the ILSS value obtained from experiment is 5.03 Mpa and 5.64 Mpa from modal analysis .The deviation between the two methods is 10.81%

Table 2Comparison of ILSS Value from Experimental and Modal Analysis for Different Angle-Ply Orientation

Angel	Max load (N)	Shear Strength (Mpa)	
		Experimental	Analysis
30^0	598	14.02	15.2
45^0	430	10.07	11.3
60^0	350	8.20	9.18
75^0	215	5.03	5.64

Table 3Comparison of Deflection Value from Experimental and Modal Analysis

Angel	Max load (N)	Deflection (MM)	
		Experimental	Analysis
30^0	598	1.11	1.11
45^0	430	0.78	0.823
60^0	350	0.61	0.669
75^0	215	0.47	0.411

VII. CONCLUSIONS

After analyzing all the results the following conclusions were drawn

- The angle ply orientations has significant effect on ILSS
- It is observed that the maximum value of ILSS was obtained at 30^0 of angle ply orientation. ILSS value decrease with increase of angle ply orientation
- ILSS and deflection decreases with increase with the load

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