Study of Mechanical Behaviour of Polymer/Glass Fibre Reinforced Polymer Matrix Composites

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ABSTRACT – The PMC's are slowly emerging form realm of advanced material & replacing conventional materials in a wide variety of applications. In this Work laminates are fabricated by a hand layup technique with and without fibres (Neat/pure matrix).The bi woven (WSM) glass fibre reinforced with polyester and epoxy resin as an adhesive. The casio4 filler material is added to resin to improve the mechanical properties. Hardener Hy-951 triethylene tetramine is added to epoxy/glass fibre & accelerator, catalyst are added to Polyester/glass fibre for activation purpose. The specimens are cut as per ASTM standards from the earlier prepared laminates. The laminated composite materials have characteristics of High modulus/weight ratio and strength/weight ratio. The samples of Epoxy/glass and Polyester/glass are tested in Electro mechanical UTM Tue-600(c).The mechanical properties of neat matrix, Epoxy/glass; Polyester/glass composites are evaluated. The measured mechanical properties of neat matrix, Epoxy/glass and polyester/glass are compared with each other. The understanding of mechanical behavior of composite materials is very essential in design and applications.

Keywords – Polyester/glass, Epoxy/glass, neat matrix, Mechanical properties, resin.

I.INTRODUCTION

Composite materials are class of materials that are combination of two or more constituents combined at macroscopic level and not soluble with each other. When these constituents are combined that offers properties, which are more desirable than the each individual property [1].Composite materials are manufactured from two or more materials to take advantage of desirable characteristics of the components [2]. In recent year, there is increasingly growth in use of polymer composites due to their ability to replace the composite materials on basis of lower density, low thermal conductivity etc. An individual glass fibre is both stiff and strong in tension and compression.

The polymer matrix composites are used in structural applications is that they offer a certain property, often stiffness, at a lower weight than alternative materials. A neat matrix does not exhibit macroscopic flow, as fluids do. Any degree of departure from its original shape is called deformation. The proportion of deformation to original size is called strain. If the applied stress is sufficiently low. The experimental evaluation of the composite material properties is quite costly and time consuming because they are functions of geometry, fabrication process, matrix [3].

Laminates are composite material where different layers of materials give them the specific character of composite material having a specific function to perform. In a matrix based structural composites, the matrix serves two paramount purposes i.e. binding the reinforcement phases in a place and deforming to distribute the stresses among the constituent reinforcing materials under an applied force.[4]

Composites cannot be made from constituents with divergent linear expansion characteristics the interface is the area of contact between the reinforcement and the matrix materials. When the surface dissimilar constituents interact with each other, the choice of fabrication method depends on matrix properties and the effect of matrix on properties of reinforcement. [5]

II.METHODOLOGY

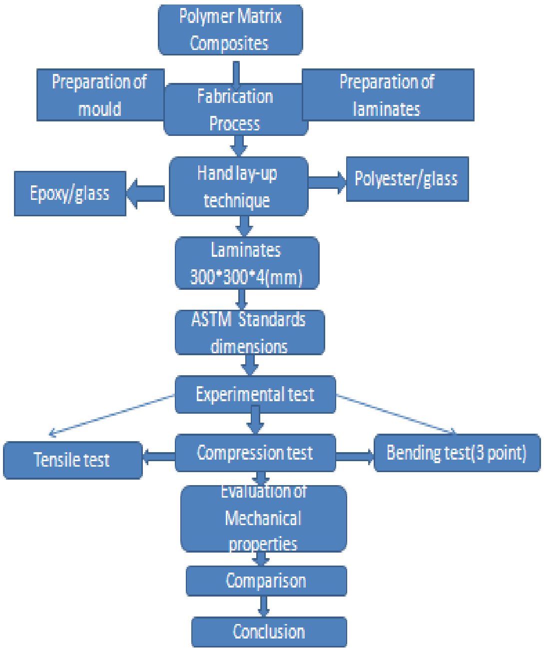

Fig 1: Methodology

III. FABRICATION PROCESS

The fabrication process involves preparation of laminates of dimension 3000*300*4(mm).In this work, the laminates are prepared fabricated by a hand layup technique with and without fibres. The laminates without fibres are called pure matrix/neat Matrix. Generally, the Epoxy and polyester resins are reinforced with 360gsm glass fibre WSM mat. Small irregularly shaped pieces made up of organic or inorganic substances used as fillers for polymers [6]. The 4% casio$_4$ filler materials is added to both Epoxy/glass and polyester/glass fibre samples to improve the mechanical properties. The 10% of hardener HY-951 Triethylene tetramine of density=0.98 kg/mm^3 that cures at room temperature. Good mechanical; strength and resistant to atmosphere and chemical degradation is added to epoxy/glass. The catalyst, accelerator is added to the polyester/glass for the purpose of activation. The 2 layers of WSM and 3layers of WSM fibre are reinforced with both epoxy and polyester samples. The laminates are cured for 12 hrs and post curing by keeping the laminates in oven for 2-3 hrs at 70deg Celsius.

Fig 2: WSM Glass fibre 300*300*4(mm).

Fig 3: Resin is added to prepared mould.

Fig 4: Load is kept to remove excess of resin.

Fig 5: Prepared laminates of neat matrix, 2L and 3L WSM reinforced epoxy/glass sample after post curing.

The prepared laminates are cut using a hand operated wire saw machine as per ASTM standards. The thickness of the specimen is 4mm. The dimensions of the test samples (flat coupons) are listed below.

Table 1: Dimensions of ASTM Specimens

Sl no	ASTM Standard	Type of specimen	Dimensions in(mm) Lbh
1	D 3039-76	Tensile	228*19*4
2	D 3410	Compression	127*10*4
3	D 790	Bending	80*25*4

L = length in (mm)

B = width of the specimen in (mm)

h =Thickness of specimen in (mm)

The Prepared epoxy/glass specimens after cutting operations as follows:-

Fig 6: Epoxy/glass samples before test.

1V.EXPERIMENTAL TEST

The prepared test samples are tested in electro mechanical universal testing machine TUE 600(c).These UTM are microprocessor based electromechanical devices with servo drive designed for testing & studying mechanical behavior of various materials like metals, polymers, elastomers.

These machines offer good built in features to offer excellent stand alone performance for standard tests and great flexibility for complex analysis. These machines confirm to IS, BS, ASTME standards. The following tests are performed in this machine to evaluate the properties.

Case I: Tensile Test

The result sheet will give the values for Extension, I and the force p in the tensile test. The tensile stress(s) is given by s = P/bh and strain/elongation is defined by strain $=I/I_o$.

The young's modulus in tension (E) is derived from linear portion of stress v/s strain graph(Experimental).

Procedure

1. Measure the width and thickness of the specimens at several locations along the narrower section in the middle. Record this number on separate sheet of paper. They will be important in analysis of your data.

2. Place the tensile specimen in the lower grip. so, that wide part of the sample is within the grip.

3. Tighten the lower jaw grip family so that our specimen is secure within the grip.

4. Apply the load gradually in steps, the load and curve graph is plotted on the display of the computer.

5. The gauge length is 50mm between the grips in a tensile test.

6. On slowly, applying the load gradually and the specimen breaks, at one particular point (peak load).

7. Now stop the cross head, return the holding grips to its initial position.

The data of load v/s displacement, stress v/s %strain is recorded.

Case II: Compression test

The result sheet will give the values of Force p in the Compression test. The compressive strength (s) is given by s = P/bh (N/mm^2).

Procedure

1. Measure the width and thickness of the specimens at several locations along the narrower section in the middle. Record this number on separate sheet of paper. They will be important in analysis of your data.

2. Place the compression specimen in the lower grip. So, that wide part of the sample is within the grip.

3. Tighten the lower jaw grip family so that our specimen is secure within the grip.

4. Apply the compressive load gradually in steps, the load and curve graph is plotted on the display of the computer.

5. On slowly, applying the load gradually and the specimen breaks, at one particular point (peak load).

6. Now stop the cross head, return the holding grips to its initial position.

The data of load v/s displacement, stress v/s %strain is recorded.

Case III: Flexural test theory

The output result file will give you the %strain & the load .The 1st step in calculating the flexural properties is to create a load v/s deflection curve. Deflection can be calculated from strain by multiplying it by span length l(the specimen length between the two support points).The flexural properties can be found by the following equations. The modulus of elasticity is calculated by finding the initial slope of the load v/s deflection curve and using the following equations;

$E_b = mL^3/4bh^3$

E_b= Flexural modulus

The maximum fibre stress for any point on the load v/s deflection curve is given by the following equation:

$S= 3PL/2bh^2$

Where;

S=stress in the outer fibres at the mid span.

P=load at the given point on the curve.

Procedure

1. Measure the width and thickness of the specimens at several locations along the narrower section in the middle. Record this number on separate sheet of paper. They will be important in analysis of your data.

2. Determine the support span; align the sample in midway between the supports.

3. Place the bending specimen in the lower grip. So, that wide part of the sample is within the grip.

4. Tighten the lower jaw grip family so that our specimen is secure within the grip.

4. Apply the flexural load gradually in steps, the load and curve graph is plotted on the display of the computer.

5. On slowly, applying the load gradually and the specimen breaks, at one particular point (peak load).

6. Now stop the cross head, return the holding grips to its initial position.

The data of load v/s displacement, stress v/s %strain is recorded.

Fig 7: specimens located in UTM for testing

Fig 8: UTM Testing Machine

V.TEST RESULTS

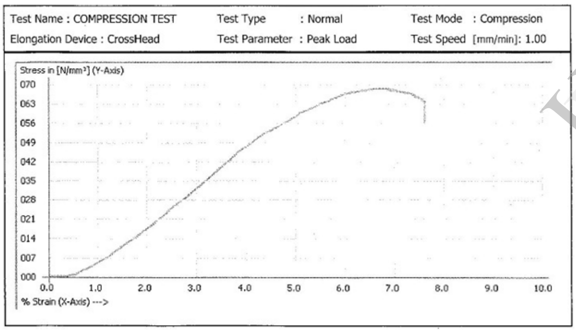

Fig 9: Polyester /glass neat matrix compression test graph

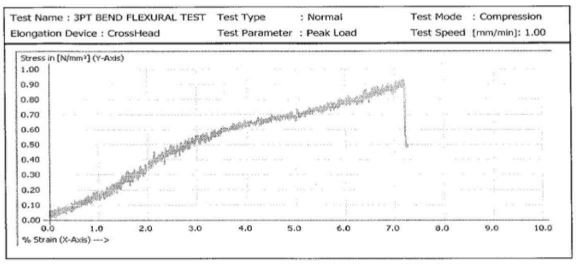

Fig 10: Polyester /glass neat matrix 3point bending test graph

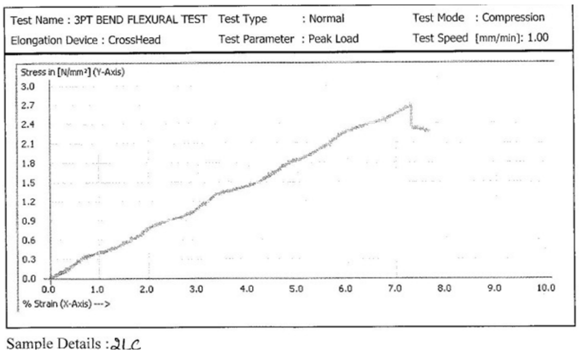

Fig 11: Bending test graph for 2LC of polyester/glass

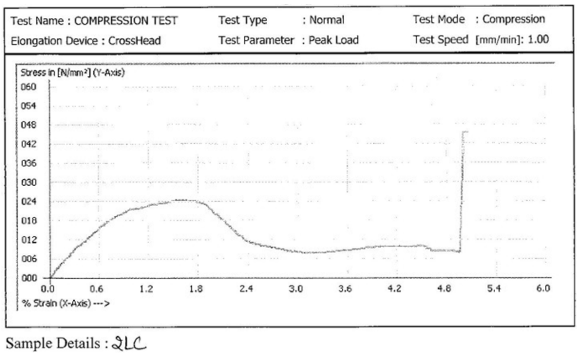

Fig 12: Compression test graph for 2 layer polyester/glass

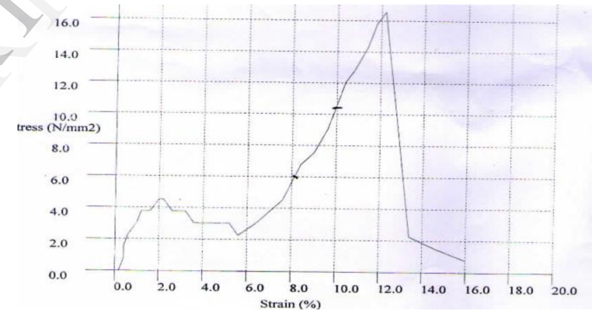

Fig 13: Epoxy /glass neat tensile test graph

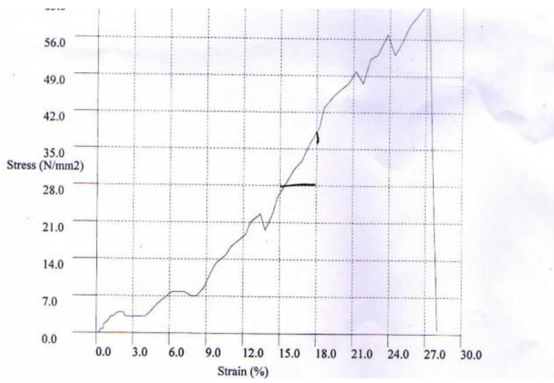

Fig 14: Epoxy /glass 2LWSM tensile test graph

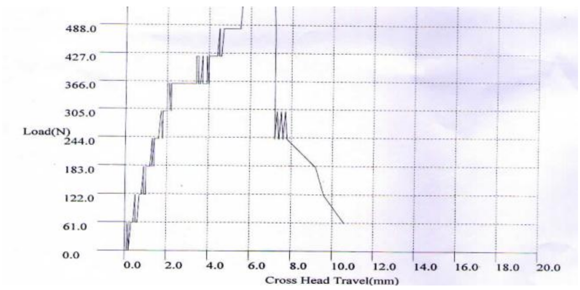

Fig 15: Epoxy /glass 3LWSM bending test graph

V1.MECHANICAL PROPERTIES

Table 2: Loading values on adding filler in %(percentage) of polyester/glass sample

Casio4 in matrix	Tensile test (N)	Bending test (N)	Compression test (N)
0%	600	142	2074
2%	725	187	2078
4%	**890**	**111**	**2547**
6%	1240	202	2970

Table 3: Strength values of neat matrix under mechanical tests of polyester/glass sample

% of filler material added	Tensile strength (N/mm^2)	Compressive strength (N/mm^2)	Flexural strength (N/mm^2)
0%	7.89	51.85	28.4
2%	9.539	51.95	37.4
4%	**11.710**	**63.675**	**22.2**
6%	16.315	74.25	40.4

Table 4: Tensile properties of Polyester/glass sample

Glass fibre	Mechanical properties	Neat Matrix	2 Layer	3 layer
WSM	Ultimate load (N)	890	2912	3512
	Tensile Strength(N/mm^2)	11.710	28.315	46.21

Table 5: Compression properties of polyester/glass sample

Glass fibre	Mechanical properties	Neat Matrix	2 Layer	3 layer
WSM	Ultimate load (N)	2547	1394	859
	Compressive Strength(N/mm^2)	63.675	42.08	26.08

Table 6: Flexural properties of Polyester/glass sample

Glass fibre	Mechanical properties	Neat Matrix	2 Layer	3 layer
WSM	Ultimate load (N)	111	129	168
	Flexural Strength(N/mm^2)	22.2	40.39	53.11

Table 7: Tensile properties of epoxy/glass sample

Glass fibre	Mechanical properties	Neat Matrix	2 Layer	3 layer
WSM	Ultimate load (N)	1320	4860	5820
	Tensile Strength(N/mm^2)	16.55	63.13	79

Table 8: Compression properties of epoxy /glass sample

Glass fibre	Mechanical properties	Neat Matrix	2 Layer	3 layer
WSM	Ultimate load (N)	360	180	480
	Compressive Strength(N/mm^2)	8.6	4	10.5

Table 9: Flexural properties of epoxy /glass sample

Glass fibre	Mechanical properties	Neat Matrix	2 Layer	3 layer
WSM	Ultimate load (N)	300	240	600
	Flexural Strength(N/mm^2)	90	72	180

VII. RESULTS

Mechanical properties

a)Young's modulus

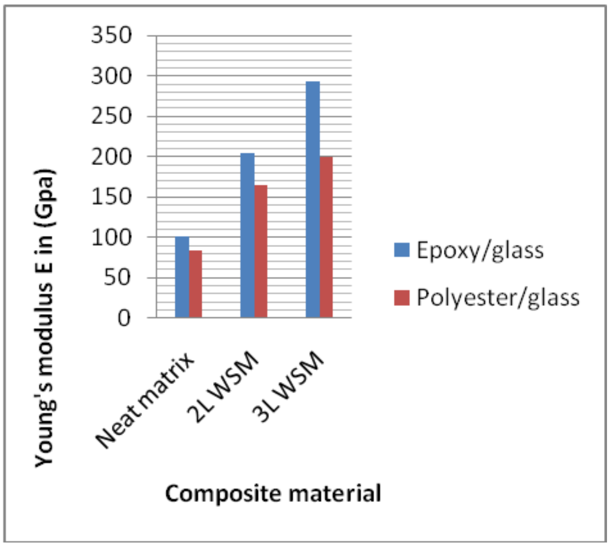

Fig 16 comparison of Young's modulus value b/w Epoxy/glass and polyester/glass

The young's modulus value of a neat matrix is always less than resin reinforced with 2L WSM and 3L WSM fibre. The 'E' of Epoxy/glass is more than the Polyester/glass samples.

B) Tensile Strength

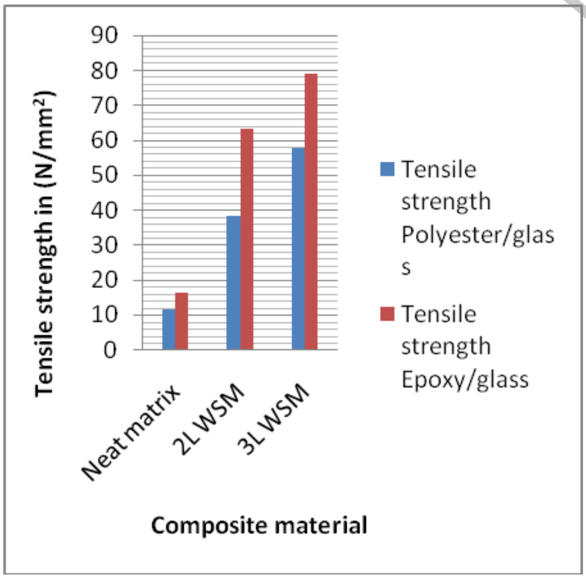

Fig 17: Comparison of tensile strength b/w Epoxy/glass and polyester/glass

From the overall comparison of tensile strength, we can conclude that tensile strength of neat matrix is always less than the 2L & 3L WSM fibre mat. Also, strength of the material increases as the no of fibres reinforced increases. The overall tensile strength in Epoxy/glass is higher than the polyester/glass.

C) Compressive strength

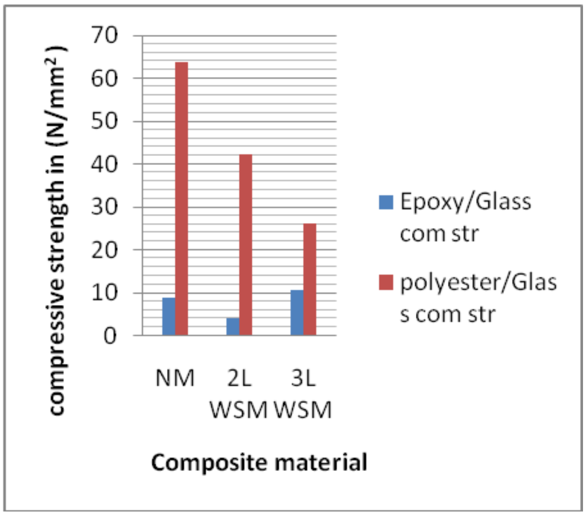

Fig 18: Comaprison of compressive strength b/w Epoxy/glass & polyester/glass

From the below fig, on adding filler material to neat matrix, compressive strength is higher .The compressive strength of the material decreases with 2L and 3L WSM mat reinforcement with polyester. The compressive strength of 3layer reinforced Epoxy/glass is more than the 2 layer.From this graph, we can conclude that compressive strength of polyster/glass fibre is much higher than Epoxy/glass fibre.

d) Flexural strength

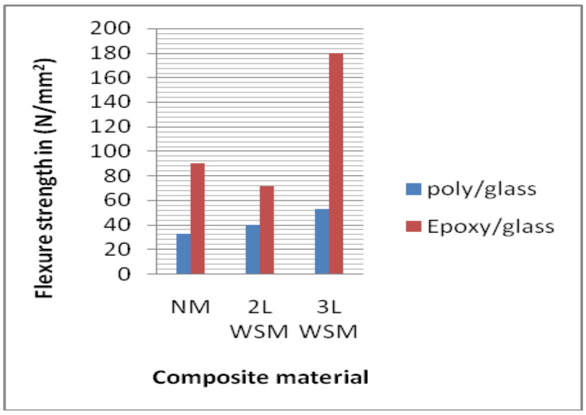

Fig 19: Comaprison of flexure strength b/w Epoxy/glass & polyester/glass

From the above graph, on comparison between Epoxy/glass and polyester glass fibre we can conclude that the flexural strength is higher in 3 layer reinforced epoxy /glass fibre than the neat matrix and 2 layer reinforced WSM fibre. On addition of fibre mat to the Epoxy/glass sample, the flexibility of the material increases than the polyester/glass.

d) Stiffness

By comparing the overall comparison of stiffness b/w epoxy/glass and polyester/glass we can say that Epoxy/glass samples is more stiffer than the polyester/glass. On considering an overall comparison between Epoxy/glass and polyester glass fibre, the stiffness in two layer reinforced glass epoxy is more than the neat matrix and 3 layered one.

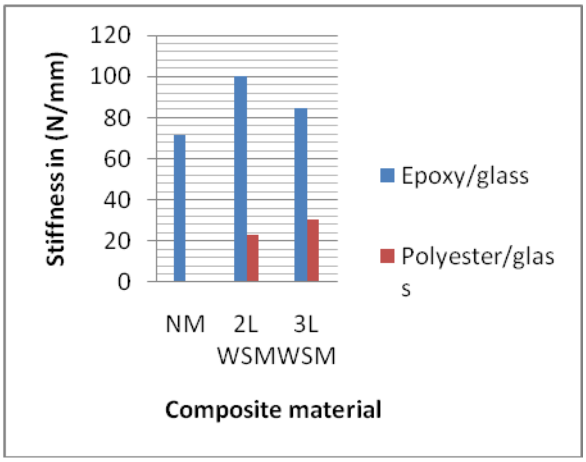

Fig 20: Comaprison of stiffness b/w Epoxy/glass & polyester/glass

VIII.SAMPLES AFTER TESTING

Fig 21 : Epoxy/glass samples of 2L WSM mat after all mechanical tests.

Fig 22 : Epoxy/glass samples of 3L WSM mat after all mechanical tests.

Fig 23 : Epoxy/glass samples of neat matrix(NM) after all mechanical tests.

IX.CONCLUSIONS

The pure/neat matrix laminates showed an inelastic behaviour under the stress strain behaviour.on adding the fillers to the neat matrix can improve the surface conditions to improve high often brittleness and stiffness.The tensile forces stretches the neat matrix well results in failure of structures easily.The tensile strength of the epoxy/glass is much higher than the polyester /glass sample.The strength of the composite material increases as the no of layers of fibre reinforced increases.The compressive strength of polyester/glass is higher than the epoxy/glass fibre.The epoxy/glass is more stiffer than the polyester/glass sample therefore, epoxy/glass fibres are widely used in automobile and aerospace applications.The tensiel strength of the material increases as the no of layers of fibre reinforced increases.

REFERNCES

[1] Keshavamurthy..et.al, Investigation of tensile properties of fiber reinforced angled ply laminated composites, International journal of emerging technology and advanced engineering.

[2 [Wang.Y..et.al, properties of composites laminates reinforced with glass multi axial non crimp fabrics j comp.

[3] Kullor and Springer G.S.et.al, Mechanics of composite structures, Cambridge university press-stand ford, 2003.

[4], P.C Pandey..et.al Basics of composite materials,, Indian institute of science,Nptel.