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TEST OF MECHANICAL BEHAVIOR IN THREE DIFFERENT RATIOS FOR GLASS-FIBER REINFORCED POLYURETHANE RESINCOMPOSITE

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ABSTRACT:
In this experimental study, the glass fiber reinforced epoxy composite is prepared and the Tensile, Transverse, Flexural, Inter Laminar Shear Stress and In Plane Stress analyzed. The glass fiber is manufactured with three types of resins (a) Epoxy LY55 (b) Epoxy LY556 with 5 % reactive diluent (c) Epofine1555 (modified epoxy resin with high elongation) and Hardener. These composites are used as sports goods, automobile bodies, etc. The glass fiber reinforced epoxy composite laminates was prepared by hand layup method and it was placed on the matched plate mould for curing. The specimen is prepared from composite laminates and the mechanical properties such as Tensile, Transverse, Flexural, Inter Laminar Shear Stress and In Plane Stress has been analyzed as per the ASTM standard D-3039, D-790, D-2344 and D-3518 respectively. For the sake of validating results ANSYS software has chosen. The material properties of each resin system is obtained based on their data sheets, using rule of mixtures the required properties (E_1,E_2,υ_{12}, υ_{23}, G_{12},G_{23}) are calculated. These values are given as inputs to the software and various tests are carried out according to the actually tested specimens. The results show the best suitable fiber resin with respect to strength.

Keywords-Composite laminate, Hand layup method, match plate mould, ASTM standard.

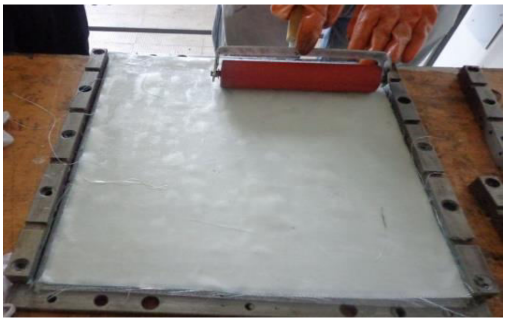
I. INTRODUCTION

Glass fibers are the most common of all reinforcing fibers for polymeric matrix composites (PMC). The principal advantages of glass fibers are low cost, high tensile strength, high chemical resistance and excellent insulating properties. The two types of glass fibers commonly used in the fiber reinforced plastics industry are E-glass and S-glass. Another type known as C-glass is used in chemical applications requiring greater corrosion resistance to acids than is provided by E-glass. E-glass has the lowest cost of all commercially available reinforcing fibers, which is the reason for its wide used in the FRP industry. S-glass, originally developed for aircraft components and missile casings, has the highest tensile strength among all fibers in use. However, the compositional difference and the higher manufacturing cost make it more expensive than E-glass. A lower cost version of S-glass called S-2 glass is also available. Glass fibers are available in the form of continuous strand roving, chopped strands and woven roving. Woven cloth is wired using twisted continuous strands called yarns. The form of woven roving is suitable for hand layup moulding. The average tensile strength of glass fiber may exceed 3.45N/mm2. The tensile strength of glass fiber may reduce due to surface damage and presence of water. The major structural applications for fiber reinforced composite are in the field of automobile components and sporting goods. In automobile applications it is classified in to three groups they are body components, chassis components and engine components. Exterior body components such as hood, door panels require high stiffness and dent resistance as well as Class-A surface finish for appearance. The composite material used for these components is E-glass fiber reinforced sheet moulding compound composite. Other body components are roof frames, door frame, bumper beams, engine valve covers, timing chain covers, oil pan etc., and 80% weight reduction. Other structural chassis components such as drive shaft and road wheels have been successfully in the laboratory and further research is going onto regularize for common use. In sporting goods application the glass fibers reinforced epoxy is prepared over wood and aluminium in pole vault poles because of its high strain energy storage capacity. A good pole must have a reasonably high stiffness and high elastic limit stress so that the strain energy of the bent pole can be recovered to propel the athlete above the horizontal bar. Other glass fiber sporting goods are surf boards, archery bows and arrows.

SHEET PREPARATION

The woven glass fiber is cut into 390mmx340mm size pieces. Epoxy and Hardener are mixed well in ratio 100 parts of resin to 27 parts of hardener. The surface of the mould is cleaned with acetone and a release agent (wax) is applied. Epoxy was applied on die plate and subsequent plies are placed one upon another. These plies are stacked layer by layer of about 12 layers to attain the thickness of 5mm as per the ASTM Standard Specimen a Teflon roller is used to remove the air gaps or voids formed between layers. Epoxy Resin is applied for each layer. Thus 3 laminates were prepared of three different types of resin. Now mould is closed with Punch plate and mould is clamped by tightening the bolts with specified torque. Torque is applied to the clamping bolts on the tool (Mould), causing the excess resin to flow of the clearance holes. The mould is now placed in the oven for curing; the process of polymerization is called "curing". The first stage in this cure cycle consists of increasing the temperature up to 120 °C and dwelling at this temperature for nearly 60 minutes when the minimum resin viscosity is reached, torque is applied on the tool (Mould), causing some more resin to flow of the clearance holes in second stage the laminate is kept for dwell of 4hrs after reaching 180 °C and finally it is allowed to cool for overnight.

Placing first the ply



Consolidating the ply by roller

closing the mould

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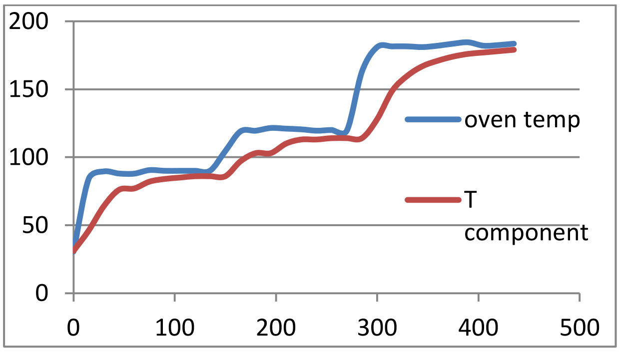
Torquing

Curing

DATA COLLECTED DURING POLYMERIZATION

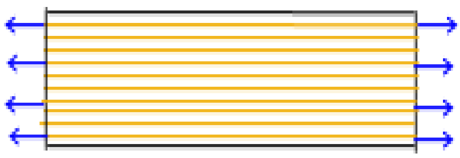
Oven and Laminate Temperature reading are collected at regular time intervals. Once the data have been gathered, the graph is plotted between time and part temperature/oven temperature.



CURED LAMINATE

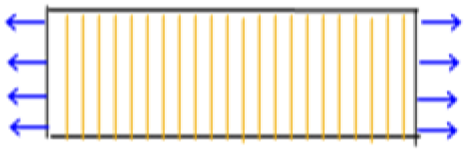
TESTING

1) Tensile Test: In this test a thin flat strip of material having a constant rectangular cross section250mmx15mmx3mm is mounted in the grips of the mechanical machine and monotonically loaded in the fiber direction as shown in Fig 3.34.The ultimate strength of the material can be determined from the maximum force carried before failure.



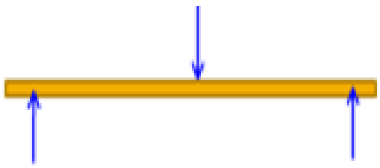
Direction of Loading in UD-Tensile

2) Transverse Test: In this test a thin flat strip of material having a constant rectangular cross section175mmx25mmx3mm is mounted in the grips of the mechanical machine and monotonically loaded in normal to the fiber direction as show in Fig 3.35. The ultimate strength of the material can be determined from the maximum force carried before failure.



Direction of Loading in Transverse Tensile

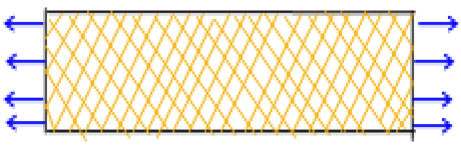
3 Flexural Test: These test methods cover the determination of flexural properties of unreinforced and reinforced plastics. However, flexural strength cannot be determined for those materials that do not break or that do not fail in the outer surface of the test specimen within the 5.0 % strain limit of these test methods. These test methods utilize a three-point loading system applied to a simply supported beam. A bar of rectangle cross section rests on two supports and is loaded by means of a loading as shown in Fig 3.36. To conduct this test the L/D ratio should be greater than 16 (L = Span length, D = Lateral dimension)



Flexural Test

In-Plane Shear:

This test method determines the in-plane shear response of polymer matrix composite materials reinforced by high-modulus fibers. The composite material form is limited to a continuous-fiber-reinforced composite 45° laminate capable of being tension tested in the laminate x direction as shown in Fig 3.37.



Direction of Loading in In-Plane Shear

A uni-axial tension test of a 45° laminate is performed in accordance with Test Method D 3039, although with specific restrictions on stacking sequence and thickness. This test method is designed to produce in-plane shear property data for material specifications, research and development, quality assurance, and structural design and analysis. Factors that influence the shear response and should therefore be reported include the following: material, methods of material preparation and lay-up, specimen stacking sequence and overall thickness, specimen preparation, specimen conditioning, environment of testing, specimen alignment and gripping, speed of testing, time at temperature, void content, and volume percent reinforcement.

3.6.2.5 Short-Beam Test:

This test method determines the short-beam strength of high-modulus fiber-reinforced composite materials. The specimen is a short beam machined from a curved or a flat laminate up to 6.00 mm [0.25 in.] thick. The beam is loaded in three-point bending.

S.No.	TEST	AVERAGE STRENGTH (MPa)		
		RESIN SYSTEM 1	RESIN SYSTEM 2	RESIN SYSTEM 3
1	TENSILE TEST	282	302	372.4
2	TRANSVERSE TEST	224	242	318
3	FLEXURAL TEST	177	185	213
4	INTER LAMINAR SHEAR STRESS	56	61	76
5	IN-PLANE STRESS	80	87	112

Application of this test method is limited to

continuous- or discontinuous-fiber-reinforced polymer matrix composites, for which the elastic properties are balanced and

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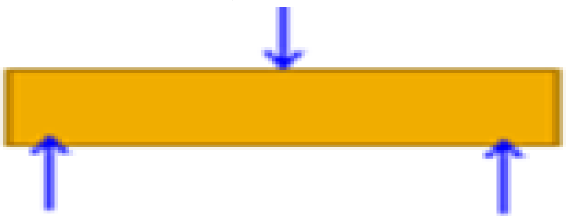
symmetric with respect to the longitudinal axis of the beam.

The short-beam test specimen is center-loaded as shown in Fig 3.38. The specimen ends rest on two supports that allow lateral motion, the load being applied by means of a loading nose directly centered on the midpoint of the test specimen. However, failures are normally dominated by resin and inter laminar properties, and the test results have been found to be repeatable for a given specimen geometry, material system, and stacking sequence. Short-beam strength determined by this test method can be used for quality control and process specification purposes. It can also be used for comparative testing of composite materials, provided that failures occur consistently22 in the same mode. To conduct this test the L/D ratio should 2be less than 1/4 (L = Span length, D = Lateral dimension)

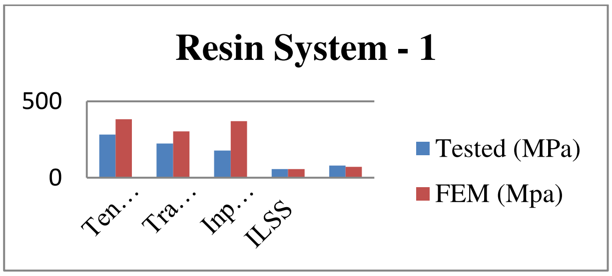


Short Beam Shear Test

By using ANSYS the analytical results of Tensile, Transverse, Flexural, Short Beam, In-Plane Stresses were obtained of the laminate of three types of resin systems.

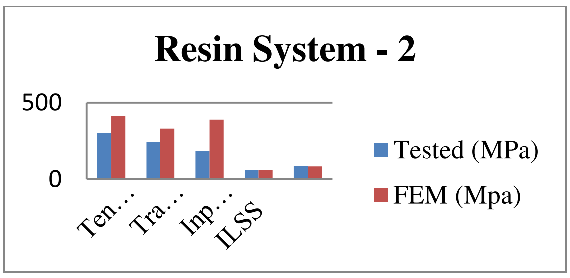
RESULTS & DISCUSSION

The overall tested results of all three resin systems are tabulated below Comparison of tested results of all resin systems The analytical Results from ANSYS are tabulated below Comparison of FEM results of all resin systems



Comparison of Resin system 1 Properties

S.No.	TEST	AVERAGE STRENGTH (MPa)		
		RESIN SYSTEM 1	RESIN SYSTEM 2	RESIN SYSTEM 3
1	TENSILE TEST	382	414	518
2	TRANSVERSE TEST2	304	331	440
3	FLEXURAL TEST	72	83	103
4	INTER LAMINAR SHEAR STRESS	57	59	84
5	IN-PLANE STRESS	369	388	449



Comparison of Resin system 2 Properties

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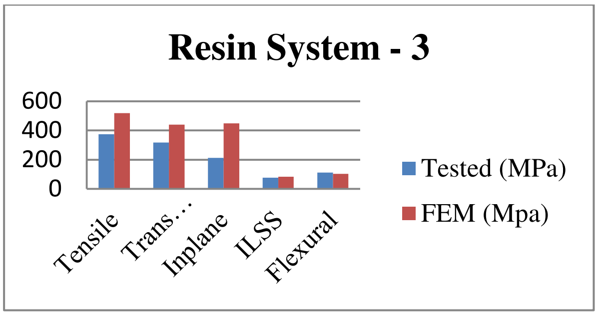
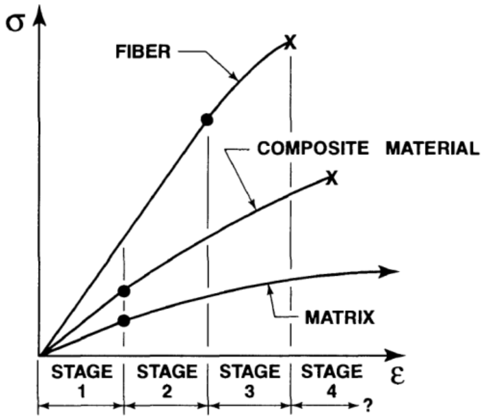


Comparison of Resin system 3 Properties

Materials (Fiber) can be such that, they have high modulus as well as high strength. Matrix material in general has very low value of modulus and strength. However it is possible to enhance the modulus of matrix material by addition of certain modifiers though strength may not increase.

From the strength theories it is a known factor that, the strength of a composite is lies in between the stress strain curve of fiber and matrix as given in the following figure.



Deformation stages of a fiber reinforced composite material

As shown in the above figure, if we consider the stress strain curve into four stages, in the first stage both the fiber and matrix are within elastic region. In the second stage the fiber is in elastic zone and the matrix entered into plastic zone. In the third stage both the fiber and matrix are in plastic zone. In the fourth stage the fiber reached ultimate value and has broken and the matrix is continued in the plastic zone. So as a result the composite behaves as elastic in first stage. From second stage onwards it entered into plastic zone. So finally the composite will fail in the fourth stage with a lesser strength when compared with fiber strength.

So, in this present investigation the modulus of matrix has increased to get higher strength and good compatibility. After introducing the reactive diluents the strength has increased to some extent (20MPa) resulting in higher strength. But the toughened Epoxy resin resulted in best bonding strength between fiber and matrix which in turn resulted in higher tensile strength. According to the tested results Resin system 3 resulted in high strength.

As the transverse strength is resin dominant property, after introducing reactive diluents the strength also increase slightly. For the resin system 3 because of the good compatibility between fiber and matrix it has resulted in high transverse strength compared to other resin systems. Whenever we discussed about flexural strengths the Resin System 3 has resulted in highest.

From the analytical point of view, the boundary conditions given are the replication of the tested results i.e. breaking loads; the resulted stresses at the gauge length are compared. The obtained tensile stresses are lesser compared to the FEM stresses because in the FEM software there is no provision of defining the fiber form i.e. if it is of continuous fiber / woven fabric / chopped strand mat.

CONCLUSION

Full advantage of the enhanced mechanical properties of the fibers like E-Glass can be fully exploited if a judicious choice of matrix system is made. This investigation was aimed at zeroing on an appropriate epoxy resin composition from among a limited number of choices resulting the following observations

- ✓ Resin System appears to be compatible with E-Glass fibers for the sizing given on it.
- ✓ As per the fig: 5.2 for resin system 1 to resin system 3 the elastic limit of resin is increasing then resulting in higher strength.
- ✓ In conclusion this experimental investigation brings out the need for compatible matrix material particularly used in conjunction with high strength fibers. The potential of high strength of the fibers can be exploited fully only when a compatible matrix is zeroed out.

Among all the resin compositions tried out, Resin System - 3 is most preferred one since it has given consistent values of tensile strength at an average in excess of **375 Mpa**. This resin system is also given reasonable good flexural, transverse tensile, in-plane shear, inter laminar shear stress.

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