International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 5, May - 2014

Synthesis and Characterization of Calcium Silicate Reinforced Polyester Composites

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Abstract –polymer composites are slowly emerging from realm of advanced materials and replacing conventional materials in a variety of applications. Laminate composite material has characteristics of high strength/weight property which suits for many structural applications. In this work, the laminates prepared using polyester matrix with addition of 4% casio$_4$ filler material. The fabricated laminates were tested for tensile, compression and Bending test. Also finite element analysis is carried out using ANSYS software for similar conditions. Finally The results of Experimental are compared with analysis results (FEA) which shows both results are almost same.

Keywords - polyester, reinforcement, composites, neat matrix.

I.INTRODUCTION

Composite material system is a class of materials that are combined with two or more constituents that are combined with two or more materials, each having different properties [1].When these constituents are combined that offers properties, which are more desirable than the each individual property[2].Composite materials are manufactured from two or more materials to take advantage of desirable characteristics of the components[3]. Composite materials do not blend to each other. The key characteristics have specific strength, specific stiffness property. 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 fiber is both stiff and strong in tension and compression .Generally, Fiber is weaker in compression it is actually on long aspect ratio of fiber [4].

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 [5].Hence, analytical models to predict these primary

Properties (stresses and strain) were developed by researchers to aid the design of composites [6].

In a neat matrix, there is no addition of fibers. These neat matrix laminates are prepared as per the ASTM standard. These specimens are tested under standard universal testing machine neat matrix materials are more appropriate when a laminate is thick or when the load path and the state of stress is structure is 3 dimensional. The example of neat matrix sample with the hole is shown in below fig1.

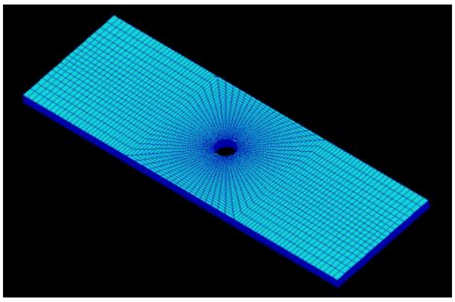

Fig 1: Example of neat matrix laminate

II.PREPARATION OF PURE MATRIX LAMINATES.

Hand lay-up is the simplest and oldest open molding method of the composite Fabrication processes. It is a low volume, labor intensive method suited especially for large components, such as boat hulls.

The mould plate is facilitated with the attachments for obtaining the laminate without glass fibers. The laminate must be squished properly to remove the air bubbles and to avoid the bending of laminate during curing or solidification. So mould is provided with top cover plate having facility of tightening by screws and can be used with or without end cover plates. When the resin is used without glass fibers, the flow of resin out of the mould will takes place if the mould is used without end cover plates, so end cover plates are used to stop the flow of resin out of the mould, and makes the mould as closed mould for fabricating the laminates with only resin.

Small irregularly shaped pieces made up of organic or inorganic substances used as fillers for polymers[7]. They are especialllly used for cross linkable, so called thermosetting plastics as extending fillers to save polymer but to improve surface conditions, improve high often brittleness and stiffness[8].

By addition of glass fibres to crosslink able polymer molding materials are produced with increased tensile strength, stiffness, as compared to filler free polymers.

Fig 2: Assembly of mold used to fabricate composites

III. METHODOLOGY

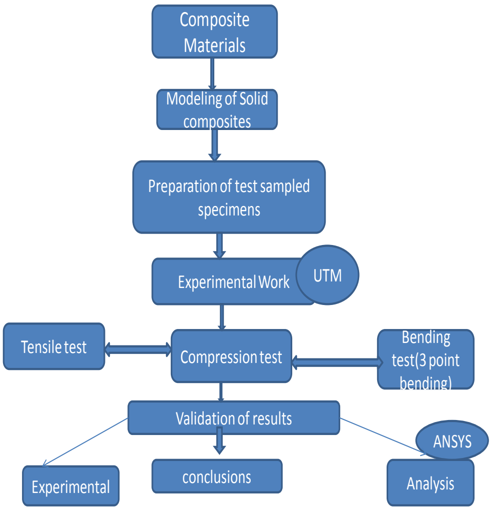

Fig 3: Methodology

IV.EXPERIMENTAL

Tensile test

The tensile properties such as tensile strength, tensile modulus, and poison's ratio were determined by a static tension test in accordance with ASTM standard specimen. The feed length is 2mm/min and specimen is held in hydraulic grips. An extensometer is mounted on specimen for measurement of strain. The one end is fixed and gradual load is applied at the other end of the specimen.

Fig4: Tensile test in Universal testing Machine

Compression test

The compressive properties such as compressive strength, compressive modulus are determined by a compression test in accordance with the ASTM standard. A compressive load is applied on the specimen by gripping at one end and gradual compressive load is applied on test specimen.

Flexural test

The flexural properties such as flexural strength and flexural modulus were determined as per ASTM Standard. The rectangular cross section specimens are loaded in three point bending with a recommended span to depth ratio. A load is applied at cross head of 2.8mm/min.

$$\sigma_{max} = 3P_{max} L /bh^2$$

V. COMPUTATIONAL DETAILS

A finite element method is used for analysis of the pure/neat matrix of tensile, compression and bending specimens laminate (without any fibers). Ansys 12.1V is used to stimulate the work of analysis. For this analysis, the behavior of neat matrix is assumed to be bi linear rate independent, in- elastic isotropic hardening behavior of materials. The tangent modulus is found by ratio of stress strain relationship after elastic limit and ultimate strength (at that load).The material Exhibits elasto plastic behavior.

VI.MODELING

The laminates are modeled as per ASTM standard dimensions using Catia V5. During modeling the thickness of laminate is assumed to be 4mm.

Case I: Tensile Test

For tensile test, a sample is prepared according to ASTM standard 610.

Dimensions

Length=228mm, width=19mm,gauge length 69mm,dia at gauge length13mm

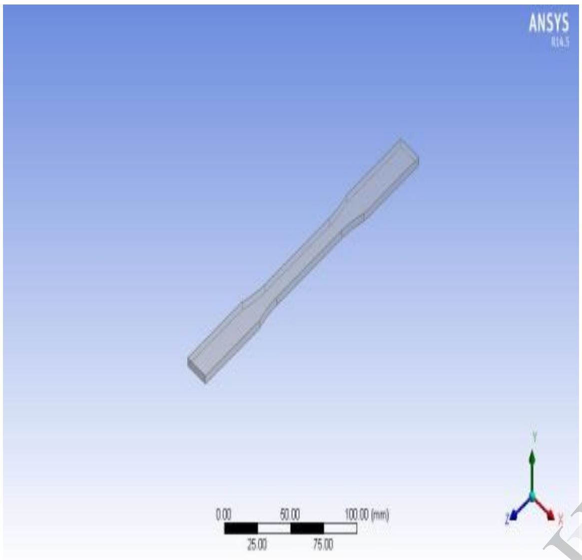

Fig 5: Tensile dog bone specimen

Case II: Compression Test

Fig6: Compression specimen

For compression test, a ASTM D340-75, standards specimens are prepared. The geometry of the specimen is rectangular.

Dimensions:-

Length 127mm, width 10mm, thickness 4mm

Case III: Bending Test

For a bending test. a sample is prepared according to ASTM standard D790.

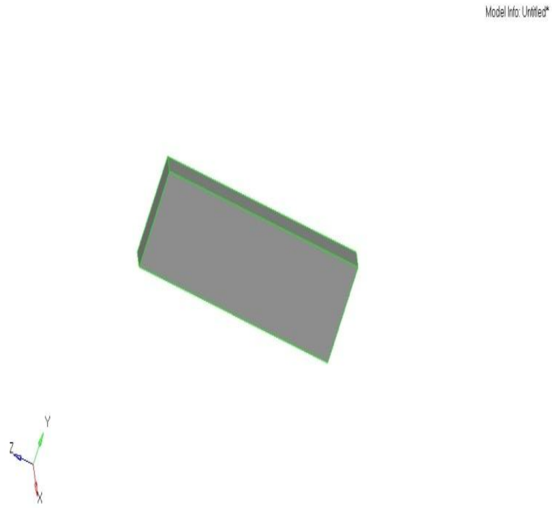

Fig7: Bending specimen

The dimensions are Length 80mm, width 25mm and thickness 4mm.

VII. ELEMENT TYPE

Solid Element

The solid quad 4 node 182 is element is used for the solid geometry. PLANE182 is used for 2-D modeling of solid structures. The element can be used as either a plane element (plane stress, plane strain or generalized plane strain) or an ax symmetric element. It is defined by four nodes having two degrees of freedom at each node: translations in the nodal x and y directions. The element has plasticity, hyper elasticity, stress stiffening, large deflection, and large strain capabilities. It also has mixed formulation capability for simulating deformations of nearly incompressible elasto plastic materials, and fully incompressible hyper elastic materials.

VIII. MATERIAL PROPERTY

Polyester resins are used in manufacturing of composites are supplied from cherry paints and polymers private limited.

Polyester resins such as these are of the 'unsaturated' type. Unsaturated polyester resin is a thermoset, capable of being cured from a liquid or solid state when subject to the right conditions. It is usual to refer to unsaturated polyester resins as 'polyester resins', or simply as 'polyesters'. There is a whole range of polyesters made from different acids, glycols and monomers, all having varying properties.

From experimental graph, We have calculated and assigned a poisons ratio, tangent modulus, and yield stress as a property values for each cases (Test). Fillers are often added in quantities up to 50% of the resin weight although such addition levels will affect the flexural and tensile strength of the laminate. The use of fillers can be beneficial in the laminating or casting of thick components where otherwise considerable exothermic heating can occur. Addition of certain fillers can also contribute to increasing the fire-resistance of the laminate.

Table 1: properties for each Mechanical test

Type of Test	E in N/mm^2	Tangent Modulus in N/mm^2	Poisson Ratio	Load in N
Tensile	1.7836e3	899.25	0.3	390
compression	1.5312e3	457.142	0.3	2547
Bending	15.3846	6.944	0.3	111

IX. RESULTS AND DISCUSSIONS

The polyester resins are mixed with a filler material calcium silicate that improves the mechanical properties. The filler material along with resin is added in percentages and samples are prepared for mechanical test. Tests are conducted for each samples and the strength are calculated.

Table 2: Results for each mechanical test on adding filler material to matrix.

$CaSiO_4$ in Matrix (%)	Tensile test in (N)	Compression test in (N)	Bending test in (N)
0%	262	2074	142
2%	301	2078	187
4%	390	2547	111
6%	258	2970	202

Table 3: strength values on adding filler material to matrix

SL no	% of filler material	Tensile strength N/mm^2	Compressive strength N/mm^2	Flexural strength N/mm^2
1	0%	3.44	51.85	28.4
2	2%	3.96	51.95	37.4
3	4%	5.131	63.675	22.2
4	6%	3.39	74.25	40.4

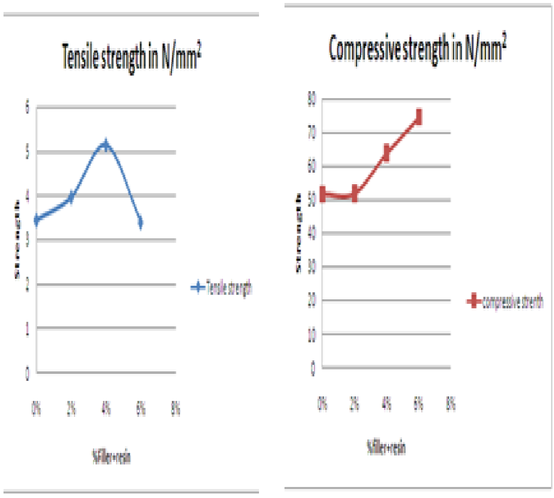

Fig 8: Tensile and compressive strength on increasing %filler with matrix

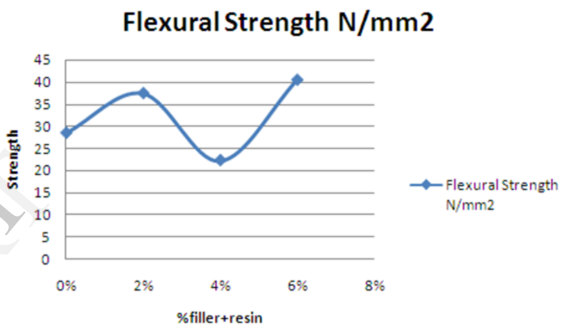

Fig9: Flexural strength on increasing %filler with matrix.

On comparison of mechanical properties by adding filler material to resin (Neat/Pure Matrix), we can conclude that the tensile strength at 4% filler material is higher. Also at 4% the flexural strength is optimum. Hence, the tensile and flexural properties have improved by adding a filler material to the resins. Also, from the graph we can say that the compressive strength increases as addition of filler material increases.

Case I: Tensile test

The load is distributed on all the nodes along one end and the other end of geometry is constrained (All DOF=0).

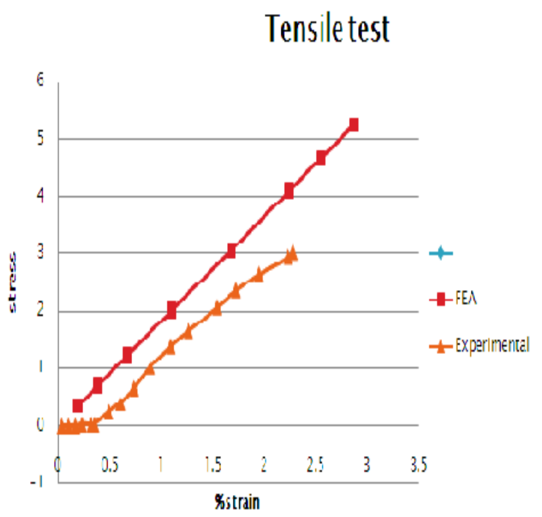

Fig10: Comparison of FEA and Experimental results for tensile test on a neat matrix.

On comparing the above experimental and analysis tensile graph of pure matrix material. We can conclude that the Analysis graph is almost matching with the Exp graph. The slight changes in graph are we have considered an offset method along strain of 0.4% of its value.

Table4 : comparison b/w experimental and numerical results of tensile test

	Exp Value	Numerical Analysis
stress	3.5	5.237
strain	0.027	0.0286

Case II. Compression test

From the below figure11, the compression graph of both experimental and numerical analysis, the nature of graph holds a good agreement with the results. The line with the blue color indicates the analysis graph and the dotted line with the red color indicates the nature of experimental graph.

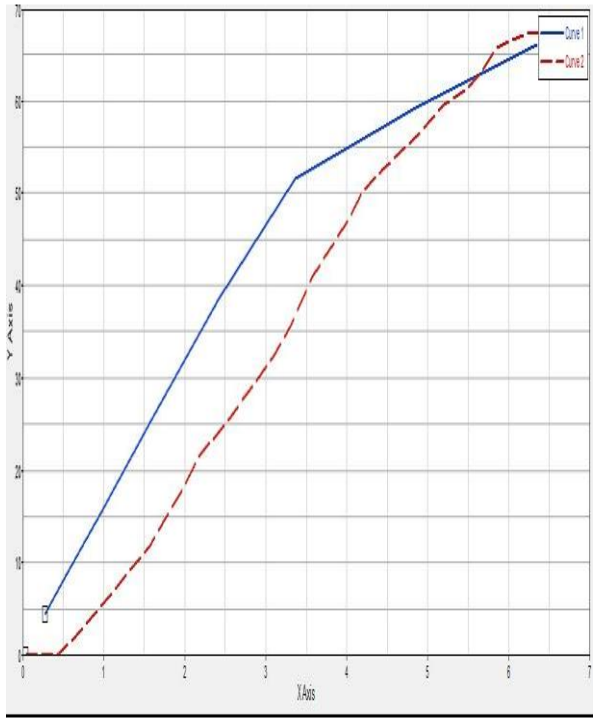

Fig11: Comparison of FEA and Experimental results for compression test on a neat matrix using Hyper Graph

Table 5: comparison b/w experimental and numerical results of compression test.

	Exp Value	Numerical Analysis
Stress	65	66.07
strain	6.8	6.348

Case III. Bending Test (3 point compressive type**)**

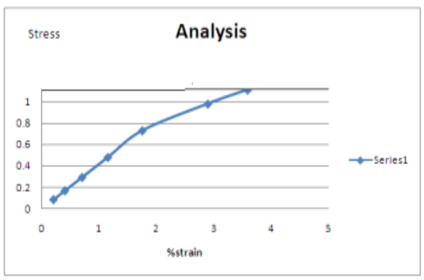

Fig12: FEA results for Bending test on a neat matrix

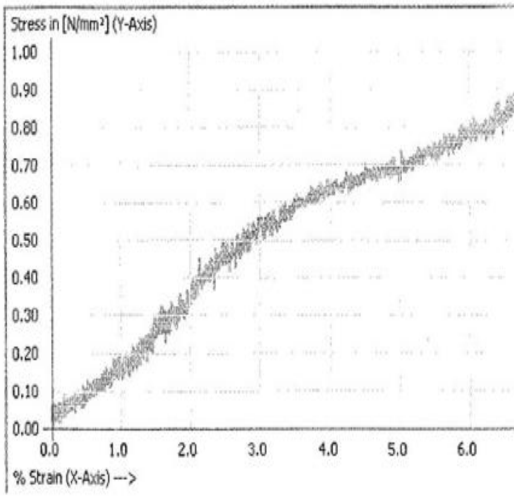

Fig13: stress v/s %strain Experimental graph of bending test

Table 6: comparison b/w experimental and numerical results of bending test

	Exp Value	Analysis
stress	0.90	1.1
strain	5	4.286

X. CONCLUSION

The laminates (neat matrix) showed an inelastic behavior between the stress and strain. Tensile forces stretches the matrix well that results in chances of structural failure easily. The tensile and flexural properties have improved by adding a filler material to the resins. There exist a good agreement with the results of experimental and numerical analysis. Finite element models constructed in ANSYS V12.1 using the dedicated element have accurately captured the tension, compression response of the system up to failure. On adding the fillers to the neat matrix (polyester) can improve the surface conditions to improve high often brittleness and stiffness.

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