EFFECT OF VOLUME FRACTION OF CHOPPED GLASS FIBRES ON TENSILE AND THERMAL PROPERTIES OF POLYMER MATRIX COMPOSITE

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Abstract—* Composite are replacing the conventional materials by meeting the requirements of industries. The advantage with composite material is of stiffness and strength together with light in weight. Composites reinforced with discontinuous fibres are classified as short fibre composites. The project work deals with preparation of short fiber (chopped E-glass) reinforcement composite specimens containing polyester as matrix and chopped glass fibre strands as reinforcement material. The composite material specimens prepared by open mould method. The tensile test carried out to find out ultimate tensile strength and young's modulus. The tests are conducted as per ASTM standard sizes and procedures (D-3039). And studying its thermal properties with the help of Lee's disc method.

***Index Terms—* PMC, Chopped glass fibers, Hand layup, tensile properties, Lee's disk apparatus, Thermal conductivity, etc…**

1. INTRODUCTION

Composite materials have a wide range of applications in different engineering fields such as offshore structures, ships, aerospace structures, civil engineering structures, maritime components, chemical industrial applications, mechanical industries, etc. the applications are either weight critical such as in aerospace. Performance critical such as the nonmagnetic and noncorrosive composites in marine mine hunters. The short fibre reinforced polymer matrix composite consists of discontinuous fibres of relatively small, variable length and incorrect orientation in the continuous polymer matrix. Most short fibre composites are based on polymer matrices. These polymers form a major part of the composite materials used in the fields of automotive, shipbuilding, construction, aerospace and home applications. The fibres used to prepare the short fibre reinforced polymer matrix composites are mainly glass and also use carbon, graphite and natural fibres. Glass fibre reinforced composites have wide range of applications in an aeronautics commercial enterprises for their particular quality and solidness. Random chopped RFC'S are capable option materials for structures with lesser weight because of their large scale production capacity and minimal effort.

1.1 POLYMER MATRIX COMPOSITE (PMC's)

PMC's are consists of variety of short/continuous fibres bound by organic polymer matrix Polymers can be processed easily, having light in weight, and suitable for mechanical properties hence polymers make ideal material. It follows, therefore these are used widely as a standard in structural applications. The use of composite materials, because the overall performance of composite materials than the reinforcement of the overall performance of the larger components.

Short fibre reinforced polymer (SFRP) composites are exceptionally alluring a result of their multipurpose properties and large scale manufacturing. Expulsion aggravating and infusion forming are ordinary methods for quick assembling of thermoplastics

2. OBJECTIVE

Following are the objectives of the project

- Prepare the chopped glass fibre reinforced composite using the open mould method
- To study the effect of volume fraction of glass fibres on the tensile and thermal properties of composite
- Evaluation of the mechanical properties such as tensile strength and young's modulus of the composite
- Evaluation of thermal properties with the help of Lee's disc method

3. MATERIALS AND PROPERTIES

3.1 Chopped Glass fiber

Properties	
Density	2.5gm/cc
Thermal conductivity	0.76W/m-K
Chopped length	3mm
Diameter	1.7μm
Young's modulus	72.3 GPa

Table No.1 Properties of chopped glass fibre

3.2 Matrix Material Polyester Resin

Density	1.12 gm/cc
Thermal conductivity	0.072 W/m-K
Young's modulus	3.3 GPa

Table No.2 Properties of polyester resin

3.3 Hardeners for polyester

The hardener for the polyester is MEK hardener and also with the hardener it is necessary to add the accelerator that is blue cobalt.

4. MANUFACTURING OF COMPOSITE SPECIMENS

The manufacturing process of the composites requires mould of required shape of the composite plate. The proper proportion of resin and hardner is mixed to make the matrix. Then gently fibres are added to the matrix with proper calculations and proportions. The mixture of fibres and matrix is poured to the mould properly it is kept for curing of period 24 hour.thhe detailed Step by step procedure for the preparation of the composite plate listed below.

- Mould cleaning
- Applying mould release wax polish
- Adding glass fibres with resin
- Adding the hardner to the resin
- Stirring the composite mixture
- Pouring the composite mixture to the mould
- Adding the hardner to the resin
- Stirring the composite mixture
- Pouring the composite mixture to the mould

The composite mixture spread over the mould and takes its shape. Now the top plate is closed on the mould. This is kept for the curing for 48 hours of time period. The curing is made under room temperature

After 48 hours of time period the top plate is gently removed from the mould and then the component is removed from the mould by using the wooden stick. The wooden stick is preferred for the removing of the component from the mould because to reduce the defects of the component.

Same procedure is repeated for all three volume fractions by changing the volumes of glass fibre and matrix as per the calculations.

For first volume fraction 1% of chopped glass fibre and 99% of resin is taken, for second volume fraction 2% chopped glass fibre and 98% of resin is taken and for third volume fraction 3% chopped glass fibre and 97% of resin is taken.

4.1 Cutting of tensile Specimens using water jet cutting machine:

The manufactured chopped glass fiber reinforced composite specimens are cut as per the ASTM Standard. The ASTM standard for tensile testing dimensions of specimen is explained as follows:

The dimension of tensile testing according to the ASTM standard D 3039.This standard is applicable for the random, continuous and discontinuous fibers composite so moreover the dimensions which we consider for the cutting of these sheets as 250*25*6 mm as (Length*Gauge length*thickness).

The cutting of the composite sheet is made on the abrasive water cutting jet machine

From each sheet of size 300*300*6, total 5 specimens of size 250*25*6 are cut

Figure No.1 Cutting of specimens using water jet machine

5. EXPERIMENTAL TESTING

5.1 Testing Of Tensile Specimens

The tensile test are done according to ASTM standard D 3039 “standard test method for tensile properties of polymer matrix composite [7]. The tensile testing for specimens are tested by using UTM which gives the computerized perusing results. The UTM is connected with data acquisition system which functions as the conversion and measuring of mechanical motion into electrical graphics system. As for the varied composition of fibers and matrix the results of the specimens can also vary like peak load, yield stress and tensile strength. The three volume fraction composite sheets are considered.

Figure No. 2 Testing of tensile specimens

The specimens are held in the grippers or in fixture of the UTM machine and tensile load is applied up to the failure of the specimen. Simultaneously the corresponding graph of stress strain curve and also load vs cross head travel can get from the system. The same procedure is repeated for all the specimens of different volume fraction. The corresponding parameter is recorded and the date is printed on the report template which has all the details of specimens.

5.2 Finding Thermal Conductivity Using Lee's Disc Method

The effect of fiber volume fraction of the chopped glass fibre on the thermal conductivity of the chopped glass fibre reinforced polyester matrix composite specimens using Lee's disk method. Different fiber volume fraction of glass fibers were used (1%, 2%, and 3%) for the preparation of composite specimens using polyester as matrix.

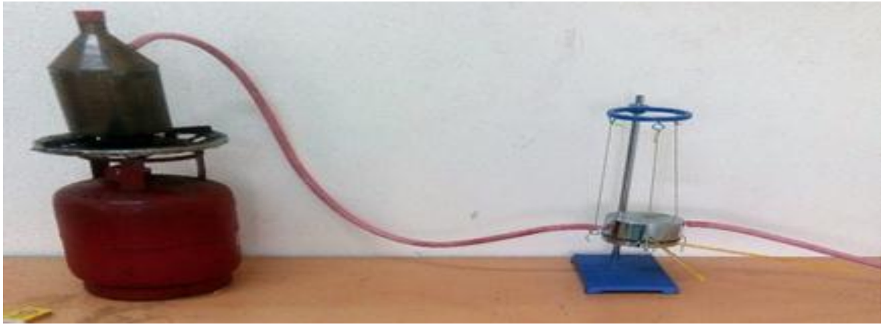


Figure No.3 Arrangement of lee's disk apparatus

Figure No.4 Circular disk shaped specimens

The specimens are prepared using circular moulds of diameter 100mm. for three volume fractions (Glass fibres in the matrix1%, 2% and 3%) total 9 specimens are prepared for each volume fraction three specimens.

6 RESULTS AND ANALYSIS

6.1 Tensile test results

Young's modulus (tensile modulus) of test specimens are calculated from the graphs. Theoretical calculations are made using two approaches

6.1.1 Halpin Tsai model [5]

$$\mathbf{E_{Random}} = \frac{\mathbf{3}}{\mathbf{8}}\mathbf{E_{11}} + \frac{\mathbf{5}}{\mathbf{8}}\mathbf{E_{22}} \qquad (1)$$

Where

$$E_{11} = \frac{1 + 2(l_f/d_f)\,\eta_L V_f}{1 - \eta_L V_f} \times E_m \qquad (2)$$

$$\eta_L = \frac{(E_f/E_m) - 1}{(E_f/E_m) + 2(l_f/d_f)} \qquad (3)$$

$$E_{22} = \frac{1 + 2\eta_T V_f}{1 - \eta_T V_f} \times E_m \qquad (4)$$

$$\eta_T = \frac{(E_f/E_m) - 1}{(E_f/E_m) + 2} \qquad (5)$$

E_{11} is longitudinal tensile modulus
E_{22} is transverse tensile modulus
E_f is tensile modulus of glass fibre
E_m is tensile modulus of matrix
l_f is length of glass fibre
d_f is diameter of glass fibre

6.1.2 Pan's model [6]

Pan developed a new approach to calculate the elastic modulus for the randomly oriented discontinuous fibre reinforced composites. he used volume fractions and elastic modulus of the fibre and matrix to calculate the elastic modulus of the composite for two dimension case

$$\mathbf{E_C^{2D}} = \mathbf{E_f}\frac{\mathbf{V_f}}{\boldsymbol{\pi}} + \mathbf{E_m}\left[\mathbf{1} - \frac{\mathbf{V_f}}{\boldsymbol{\pi}}\right] \qquad (6)$$

Specimen No.	C/S area (mm^2)	Tensile strength (N/mm^2)	Tensile modulus(GPa)
1	139.12	31.051	2.995
2	138.92	17.564	2.879
3	138.22	36.752	2.654
4	143.98	26.393	2.662
5	141.66	32.754	2.911
Average			**2.820**
Halpin Tsai equation			**3.59**
Pan's model			**3.59**

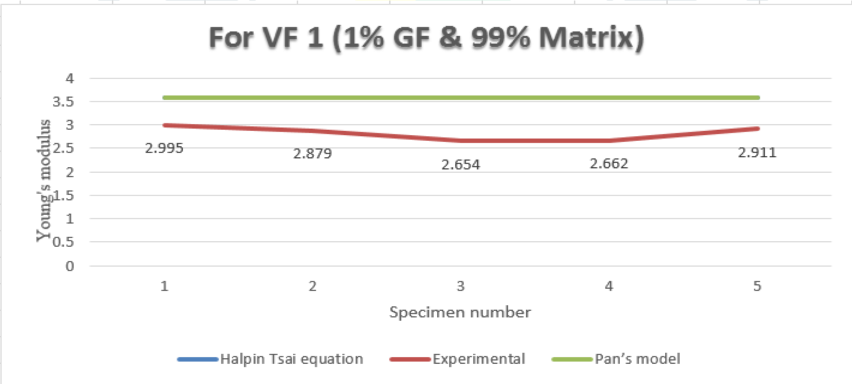
Table No.3 Tensile test results of volume fraction 1

Specimen No.	C/S area (mm^2)	Tensile strength (N/mm^2)	Tensile modulus(GPa)
1	142.55	21.046	3.507
2	140.45	25.775	3.559
3	140.55	16.791	3.557
4	142.46	14.881	3.509
5	140.54	21.488	3.702
Average			**3.566**
Halpin Tsai equation			**3.90**
Pan's model			**3.81**

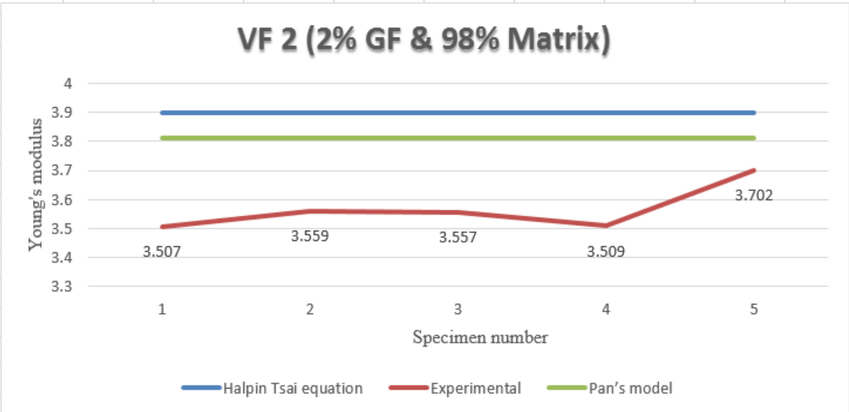
Table No.4 Tensile test results of volume fraction 2

Specimen No.	C/S area (mm^2)	Tensile strength (N/mm^2)	Tensile modulus(GPa)
1	147.18	28.535	3.821
2	138.86	28.513	4.050
3	145.58	22.256	3.8161
4	145.51	26.116	3.9648
5	142.53	25.679	3.9465
Average			**3.92**
Halpin Tsai equation			**4.182**
Pan's model			**4.038**

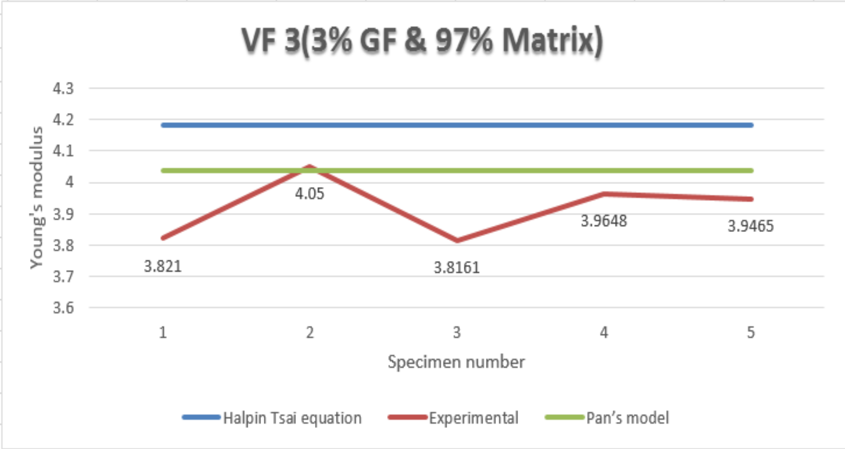
Table No.5 Tensile test results of volume fraction 3



Graph No.1 Comparison of theoretical and experimental results of volume fraction 1



Graph No.2 Comparison of theoretical and experimental results of volume fraction 2



Graph No.3 Comparison of theoretical and experimental results of volume fraction 3

6.2 Thermal conductivity

The thermal conductivity (k) of the specimen calculated using Equation

$$K = \frac{mS\left(\frac{dT}{dt}\right)d(r+2h)}{\pi r^2(T_1 - T_2)2(r+h)} \qquad (7)$$

Where

Steady temperature of steam chamber (T_1) = It is taken from the experiment in K

Steady temperature of the lower cylinder (T_2) = It is taken from the experiment in K

Mass of lower cylinder (m)

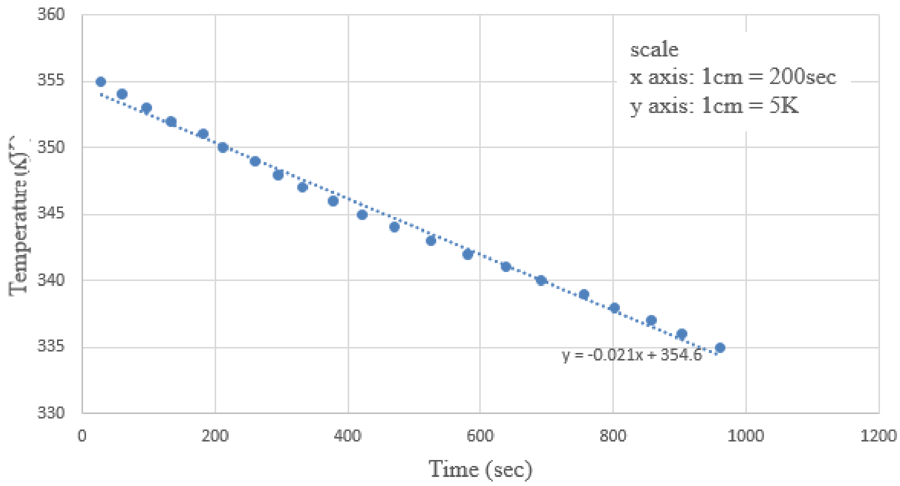
Specific heat capacity of cylinder(S)

Thickness of the specimen (d)

Thickness of cylinder (h)

Radius of cylinder (r)

Mean rate of fall temperature at mean temperature T_2 $\left(\frac{dT}{dt}\right)$= It is taken from the graph of temperature v/s time



Graph No. 4 Temperature v/s time

Specimen no.	Thermal conductivity K ($Wm^{-1}K^{-1}$)
1	0.08219
2	0.0851
3	0.07855
	$K_{Average}$ = 0.0807

Table No.6 Thermal conductivity of specimens of volume fraction 1

Specimen no.	Thermal conductivity K ($Wm^{-1}K^{-1}$)
1	0.08285
2	0.0898
3	0.08454
	$K_{Average}$ = 0.0857

Table No.7 Thermal conductivity of specimens of volume fraction 2

Specimen no.	Thermal conductivity K ($Wm^{-1}K^{-1}$)
1	0.09043
2	0.08685
3	0.089057
	$K_{Average}$ = 0.88779

Table No.8Thermal conductivity of specimens of volume fraction 3

CONCLUSION

The experimental results gives following conclusion Using different volume fraction of chopped glass fibres in polyester resin the composite sheets are prepared by hand layup method. The tensile test results shows that increase of volume of chopped glass fibres in polyester resin results in increase in tensile modulus of the composite. From lee's disk apparatus experiment it shows that the increase in volume of chopped glass fibres in polyester matrix increases the thermal conductivity of the composite.

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