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Full Length Research

Investigation of Young's Modulus and thermal conductivity of epoxy based composite fiberglass material

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ABSTRACT: In this research work, an investigation was made on the Young's Modulus and thermal conductivity of fiberglass material reinforced with epoxy resin and hardener gum. Composites are made up with epoxy resin: hardener gum mixture of 10:1 ratio. Dog bone type specimen with end tab samples were prepared in different layers to find the Young's modulus by center-loaded method and thermal conductivity by Lee's apparatus method. Experimental results show that the Young's Modulus increases when increasing the number of layers and amount of epoxy resin and hardener gum mixture apply on it. However, the thermal conductivity depends on the thickness of fiberglass mat reinforced with hardener gum and epoxy resin mixture.

Keywords: Epoxy resin, fiberglass mat, hardener gum, thermal conductivity, Young's Modulus.

INTRODUCTION

Now a days in most of the developing countries, fiberglass is used as a low cost and locally available of raw material with energy saving and best replacement for wood. In developed countries, they are preferred for their non-toxicity and easy disposability. Fiberglass properties, epoxy resin properties, and fiberglass – epoxy resin and hardener gum interface properties are the three factors that are important for obtaining high strength composite materials (Kalita et al., 2015). The interface between fiberglass and epoxy resin and hardener gum mixture can be defined as a two-dimensional boundary between the fiberglass materials with resin surface (Committee on High performance, 2005). The term composite can be defined as a material composed of two or more different materials, with the properties of the resultant material being superior to the properties of the individual materials that make up the composite (Reddy et al., 2014). Different materials can be combined on a microscopic scale, such as in alloying of metals, but the resulting material is, for all practical purposes, macroscopically homogeneous, i.e., the components cannot be distinguished by the naked eye and essentially act together. The advantage of composite materials is that, if well designed, they usually exhibit the best qualities of their components or constituents and often some qualities that neither constituent possesses. Some of the properties that can be improved by forming a composite material are strength, fatigue life, stiffness, temperature-dependent behavior, corrosion, thermal insulation, wear resistance and weight. Composite materials are nowadays employed in many engineering structures, such as helicopter and wind turbine rotor blades, boat hulls and buildings, implying the application of variable loadings for long time spans (Kotiveerachari and Reddy, 1999; Reddy and Sagar, 2010).

It's clearly there are considerable improvement on mechanical properties of epoxy based composites with the mixing of micro fillers, which acts as additional reinforcing components and enhances their mechanical properties and also reduces the processing cost significantly. The properties of these composites depend upon the type, size and weight percentage of the filler material used (Rajaa et al., 2013; Devendra and Rangaswamy, 2013). More over graphite particles can be improved erosive wear resistance of glass fiber epoxy composites (Basava and Harirao, 2011).

In this project the fiberglass mat reinforced with epoxy resin and hardener gum and samples with different layers were prepared to analyze some physical properties.

MATERIALS AND METHOD

Sample preparation

The dog bone type specimen with end tabs is used for tensile test as similar to the standard shape for the tensile strength and tensile modulus (Mohammed et al., 2015) with the dimension of 50 cm (L) ×10 cm (W), the matrix was prepared by mixing the hardener gum to epoxy resin. The epoxy resin and hardener gum ratio were maintained at 10:1. To get the well-cured and a standard-quality specimen, the epoxy and hardener must be mixed smoothly and slowly. Initial layer of the mould was filled with epoxy resin mixture and then the appropriate quantity of fibers was placed such that epoxy mixture completely spread over the fibers. Before applying compression, efforts were made to remove all bubbles with roller. Finally, the compression pressure was applied evenly to achieve the uniform thickness and dried for 24 hours at room temperature.

For the making of good composite, the measurement of the samples should be accurate and the mixture should apply very uniformly over the fiberglass materials. Samples were prepared with accurate amount of epoxy resin: hardener gum ratio is 10:1 and this mixture is stirred thoroughly till it becomes a bit deep on the sample (Figure 1).

Hand lamination process was used to prepare the samples. Here the base plate is fixed inside the frame of the mould. For fabricating the fiberglass composites, 50% of resin-hardener mixture is used and the remaining is used for fiberglass sheets. At first, the mixed epoxy is been applied as a base layer and on top of that the glass fibers were kept. The epoxy is kept as a base because it will prevent from any air gap that may affect the entire fabrication process. The roller is used to roll the mould and for making the layer even throughout the mould. Then the process is continued for multiple layers of fiber sheet and epoxy. Finally, it is kept in the dry place for 24 hours for the drying purpose.

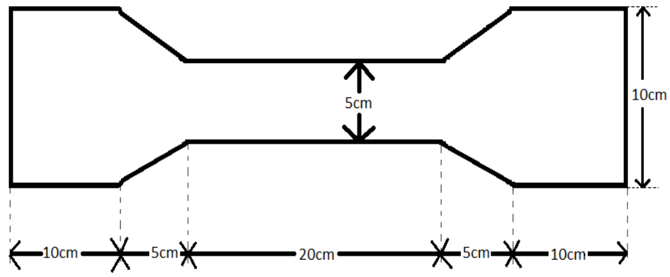

Figure 1. Young's Modulus sample.

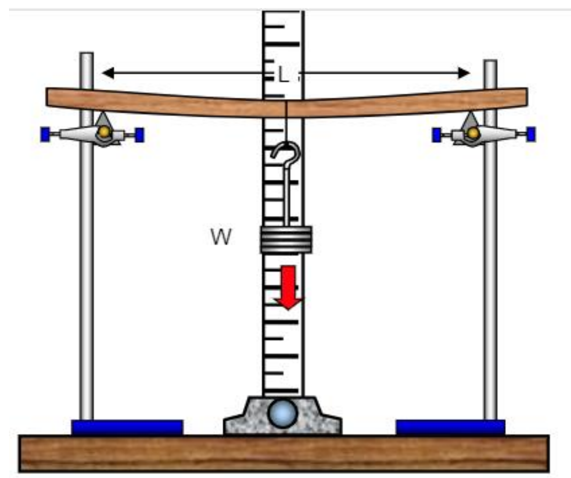

Figure 2. Experimental setup for Young's Modulus.

Experimentation

Young's Modulus

Young's modulus describes the relationship between stress (force per unit area) and strain (proportional deformation in an object). A solid object deforms when a particular load is applied to it. If the object is elastic, the body regains its original shape when the pressure is removed. With the value of Young's modulus for a material, the rigidity of the body can be determined. The experimental setup for Young's Modulus is given in Figure 2. The sample was loaded with known mass in the middle and the vertical difflection was measured by a cathetometer for different massess. The thickness and width of the sample were measured by vernier caliper and the Young's Modulus (E) was calculated by using the equation below.

$$E = \frac{L^2 g}{4bd^3} \frac{M}{y}$$

Where: E = Young's Modulus, L = Length between knife edges, g = Acceleration of gravity, M = Load, b = Width of the cantilever, d = Thickness of the cantilever, and y = Deflection

Thermal conductivity

Thermal conductivity (k), is the property of a material that indicates its ability to conduct heat. Conduction will take place if there exists a temperature gradient in a solid (or stationary fluid) medium. Energy is transferred from more energetic to less energetic molecules when neighboring molecules collide. Conductive heat flow occurs in direction of the decreasing temperature because higher temperature is associated with higher molecular energy. Fourier's law expresses conductive heat transfer as:

$$H = \frac{kA(T_2 - T_1)}{x}$$

Where H is the steady state rate of heat transfer, k is the thermal conductivity of the sample, A is the cross-sectional area and $(T_2 - T_1)$ is the temperature, x is the thickness of the bad conductor.

Thermal conductivity test was performed on the specimens (or samples) using the Lee's Disc method. The upper disc temperature T_2 and the lower disc temperature T_1 are recorded. The poor conductor is removed and the lower metal disc is allowed to heat up to the upper disc temperature T_2. Finally, the steam chamber and upper disc are removed and replaced by a disc made of a good insulator. The metal disc is then allowed to cool through $T_1 < T_2$ and toward room temperature T_0. The temperature of the metal disc is recorded as it cools so a cooling curve can be plotted. Then the slope $m = {}^{\Delta T}/_{\Delta t}$ of the cooling curve is measured graphically where the curve passes through temperature T_1.

RESULTS AND DISCUSSIONS

The dog bone type specimen with end tabs (Figure 1) is selected for tensile test as similar to the standard shape for the tensile strength and tensile modulus (Mohammed et al., 2015). The shape was reducing to small size to be broken at middle point because in previous study it was at the one end of the sample (Mohammed et al., 2015). The Young's Modulus of the sample was determined by center-loaded method (Figure 2). The middle point of the sample was loaded and deflection was measured and it was plotted (Figure 4). The slope for each layer were calculated and using the data from Table 1 and Table 2, the Young's Modulus was calculated for the respective layers (Table 3). When the number of layers increased, gradients of the solid lines were decreased and the Young's Modulus of the layers were increased with number of layers. Because the attraction between the molecules increased when increase the number of layers and amount of hardener gum and epoxy resin mixture. The properties of fiberglass depend on the amount of epoxy resin reinforced with a fiberglass mat.

Figure 3 shows the pattern of the cooling graph to calculate the thermal conductivity of a poor conductor

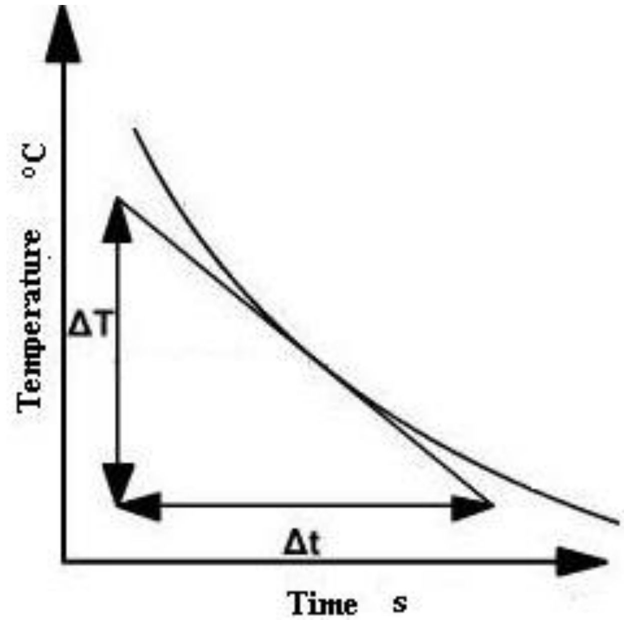

Figure 3. Cooling graph.

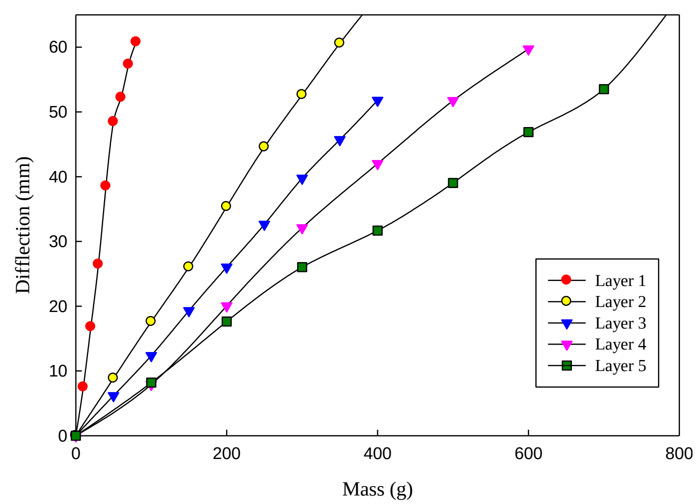

Figure 4. Graph of deflection versus Mass for different layers. The mass (g) dependence of deflection (mm) for the layers. The inset shows the expanded view of the relation. The gradient of the solid lines is inversely proportional to Young's Modulus of the layers.

sample. The slope for each layer was calculated from the experimental graph (Figure 5) and using the data from Table 4, the thermal conductivity was calculated for each layer (Table 5). When the number of layers increased, cooling time was increased with number of layers and the thermal conductivity of the layer depends on the fiberglass mat reinforced with hardener gum and epoxy resin mixture and increases with the thickness of the

Table 1. Average length and thickness for different layers (Young's modules experiment).

Layer	Average length (*l*±*0.1*) cm	Average thickness (*t*±*0.01*) mm
1	50.0	1.45
2	49.9	2.46
3	50.3	3.19
4	50.2	4.10
5	50.2	4.99

Table 2. Average width for different layers (Young's modules experiment).

Layer	Width (*w*±*0.05*) mm		
	Left end (W_1)	At middle (W_2)	Right end (W_3)
1	99.60	49.10	99.10
2	99.60	49.80	100.50
3	99.70	49.10	100.75
4	101.60	49.05	102.15
5	101.90	51.90	103.40

Table 3. Young's modulus results (Young's modules experiment).

Slope (mmg^{-1})	Young's modules x 10^3 (Nm^{-2})
0.8094	48.56
0.1719	131.58
0.1313	135.25
0.0958	141.90
0.0797	138.46

Table 4. Average thickness and diameter of different layers (Thermal conductivity).

Layer	Thickness (t±0.01) mm	Diameter (d±0.05) cm
1	1.40	2.66
2	1.69	2.69
3	2.52	2.69
4	3.44	2.68
5	4.10	2.69

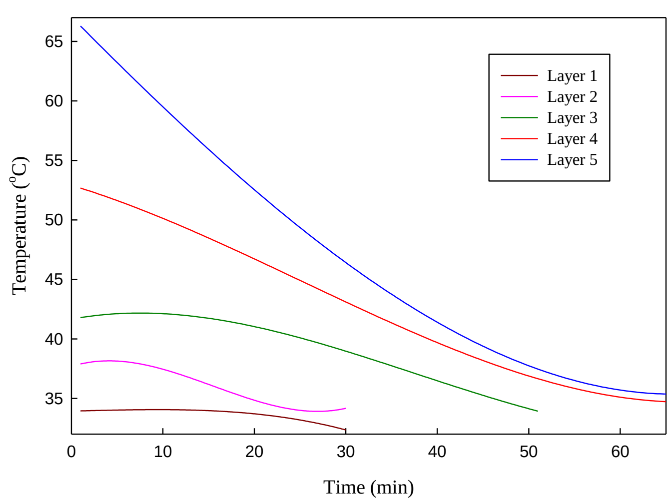

Figure 5. The graph of temperature versus cooling time for different layers. The time (min) dependence of temperature (°C) for the layers. The inset shows the expanded view of the relation. The gradient of the solid lines is proportional to Thermal conductivity of the layers.

Table 5. Thermal conductivity results (Thermal conductivity).

Layer	Thermal conductivity x 10^{-19} ($Wm^{-1}K^{-1}$)
1	0.0111
2	0.0096
3	0.0093
4	0.0253
5	0.0378

sample. The gradient of the solid lines is proportional to thermal conductivity of the layers.

Conclusion and future work

Properties of all fiberglass layers attached with hardener gum and epoxy resin mixture differ with the entire interface. Because interaction and covalent bond between the fiberglass and epoxy resin, the properties of the layers are varied. Furthermore, this study extends to:

1. Analyze the mechanical properties such as Three Point Bending Test, Water Absorption Test and Hardness Test for different layers.
2. Change the ratio of resin to hardener gum and test for mechanical and chemical properties.
3. Fiber mat can composite with natural fibers (seed fiber, leaf fiber, stalk fiber, fruit fiber) for the investigation.
4. Chemical reactions for long time interval and high concentration acids and bases.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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