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Investigation on Properties of Fiberglass with Different Layers

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Abstract- Fiberglass is known as a strong, weightless material, used in many products in day to day life. The required raw materials are very cheap, the bulk strength is high and weights are lower than many metals. Fiberglass can easily be made into intricate shapes. Fiberglass applications include aircraft, fishing boats and ships, automobiles, tubs and hulls, hot tubs, water and septic tanks, roofs, pipes, cladding, surfboards, and door siding. Aim of this work was to study the properties of fiberglass with different layers depend on the epoxy resin and a catalyst reinforced with a fiberglass mat. The ratio between the catalyst and resin was 1:10, respectively and the same amount of the mixture was used to prepare each layer. General properties such as Young's modulus, Thermal conductivity and Chemical reactions were analyzed with different layers of fiber bars and disks. The properties vary depending on the number of layers and the amount of fiberglass reinforced epoxy and catalyst. The Young's Modulus and Thermal conductivity of the layers are increase with increasing the layers of the fiber. When the sample layer is low, some chemical reactions occur, but for higher values, there is no chemical reaction.

Keywords- Fiberglass, Young's modulus, Thermal conductivity, Chemical reactions, Epoxy resin, Layers of fiberglass

I. INTRODUCTION

In developing countries, fiberglass is used in low cost, local availability of raw materials, energy saving and wood replacement. In developed countries they are preferred for their non-toxicity and easy disposability. Three factors are important for obtaining high strength composite materials: fiber properties, resin properties, and fiberglass resin interface properties [1]. The interface between fiberglass and resin can be defined as a two-dimensional boundary between the fibers with resin surface [2]. The interface between fiberglass and resin is very important, and the combined properties of all fiberglass resin interactions are due to the interface. This interaction occurs in three ways. One is a mechanical bond between two objects, the other is a surface energy bond and a secondary bond such as Vander Waals or electrostatic interactions or hydrogen bonds, and a third is a relationship between the fiber and the resin [3, 4, 5, 6].

Fibers play an important role in determining joint hardness and strength, and resin selection determines properties such as peak temperature and long-term durability [2]. Fiberglass refers to a group of products made of different types of individual glass fibers combined into a variety of forms. Fiberglass can be divided into two main groups depending on its shape. Fibers used in yarns and textiles, and the discontinuous (short) fibers used as bats, blankets, or boards for insulation and filtration.

Fiberglass is divided into five major groups such as A-glass, C-glass, E-glass, S-glass, and AE-glass. A-glass or Alkali glass Fiber has good chemical resistance but low electrical properties, C-glass or Chemical glass Fiber has very high chemical resistance, E-glass or Electrical glass Fiber is excellent insulator, S-Glass or Structural glass Fiber is optimize for mechanical properties and AE-glass or Dielectric glass Fiber has best electrical properties but lack in mechanical properties when compared to E and S glass [2].

One way to improve the strength of the Fiber reinforced composites is to add various filler materials. These filler materials act as additional reinforcing components and enhance their mechanical properties. The properties of these composites depend on the type and size of the filler material used [7, 8]. Addition of silicon carbide, alumina, and titanium carbide improves hardness, strength and wear resistance of the composites [9, 10]. Graphite particles improved erosive wear resistance of glass fiber epoxy composites [11].

In this paper, the common properties such as Young's modulus by vibration method, Thermal conductivity by Lee's dick method and Chemical reactions were analyzed with different layers of fiber bars and disks were analyzed with different number of layers and the amount of epoxy resin and catalyst reinforced with glass fiber. Section I contains introduction of Fiberglass, Section II contain some measures of prepared samples with different layers, Section III contain results and discussion and section IV concludes the research work and future directions.

II. METHODOLOGY

Fiberglass row materials were cut into layers. By changing the number of layers, five different samples were produced. Two types of chemicals were used for preparing the layers. Resin (kind of glue used to stick the layers together) and catalyst, which is improving the dryness of samples. Those were mixed for a particular ratio (catalyst: resin is 1:10), because amount of catalyst and resin will decide the thickness of the layers. A mould was designed to get identical samples as shown in Figure 1. For the layer 1 only one fiberglass mat was used. Likewise, all the samples were prepared up to layer 5, which was stiffer. Samples were dried for some time and they were removed from the mould carefully. Each layer was labeled by a number for identification. Samples dimensions were measured and tabulated in Table 1.

Figure 1. The mould and prepared layers

Table 1. Thickness and length of the samples

Layer	Sample Thickness ($t \pm 0.01$) mm				Sample Length ($l \pm 0.01$) cm		
	t_1	t_2	t_3	Avg.	l_1	l_2	Avg.
1	1.41	1.46	1.35	1.41	51.8	51.7	51.8
2	2.32	2.38	2.26	2.32	53.2	53.4	53.3
3	3.07	3.31	3.40	3.26	51.7	51.6	51.7
4	4.05	4.10	4.07	4.07	52.2	52.1	52.2
5	4.27	4.15	4.24	4.22	52.4	52.3	52.4

(a) YOUNGS MODULUS TEST

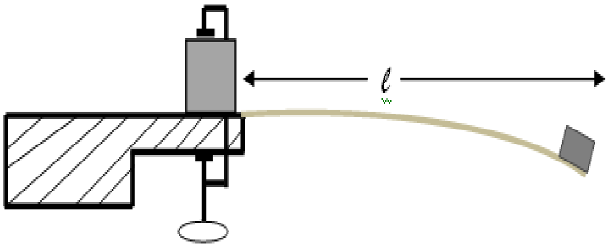

Figure 2. Experimental set up to find Young's modulus by Vibration method.

The unloaded cantilever was placed on a table top as shown in Figure 2. A mass was attached to the free end of the cantilever using a band. Small vibration given to the end of the cantilever and the time for 10 oscillations was measured. The same procedure was repeated for several lengths. If one end of the cantilever is given a small vertical displacement, the period T of the resultant oscillations is given by,

$$\boldsymbol{T^2 = \frac{16\pi^2 m l^3}{Y a b^3}}$$

Where l is the distance between the end of the bench and the free end of the beam, m is the mass, b is the breath of the beam, a is the width of the beam and Y is the Young's modulus of the beam.

(b) THERMAL CONDUCTIVITY TEST

Lee's disk experiment is shown in Figure 3, determines an approximate value for the thermal conductivity of a low-quality conductor such as fiberglass, glass, cardboard, etc. Lee's disk mechanism consists of a 5 cm deep hollow cylinder (steam chamber) of the same diameter. It has inlet and outlet pipes for steam propagation and radial holes to insert thermometers. Thermal conductivity is the property of a material, indicates the ability of a material to conduct heat. When steam is passed through a cylindrical container a stable state is soon reached. In steady state, the heat retained through the corroded conductor is equal to the heat emitted by the Lee's disc.

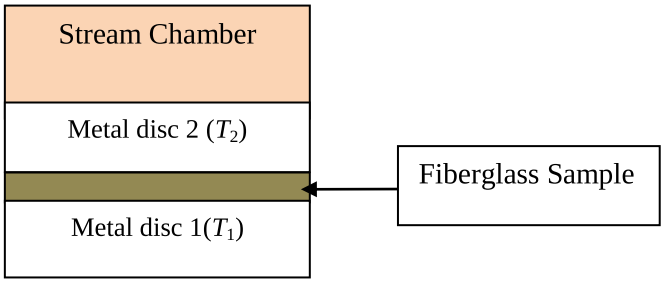

Figure 3: Experimental set up of Lee's method to find Thermal Conductivity.

The process involves placing an experimental disk, which made of a poor conductor with radius r and thickness x, between two metallic conductivity metal disks. Hot stream is passing through the stream chamber to heat up the upper metal disk and at steady state, the temperature of upper disc is T_2 and the lower disc is T_1. Then the metal discs are allowed to cool through $T_1 < T_2$ are moved to room temperature T_0.
The temperature of the metal disc is recorded as it cools so that the cooling curve can be plotted.

Then the slope $S = {}^{\Delta T}/_{\Delta t}$ of the cooling curve is measured graphically, the curve passes through the temperature T_1.

In the steady state, the heat transfer rate (H) is determined by the thermal is given by;

$$H = kA\left[\frac{T_2 - T_1}{x}\right]$$

Where k is the thermal conductivity of the sample, A is the cross sectional area of the sample, $[T_2 - T_1]$ is the temperature difference across the sample and x is the thickness of the sample.

Figure 4 shows the prepared disc samples and its average thickness and diameters are tabulated in Table 2. It is shaped like a thin disc with a large cross sectional area $A = \pi r^2$ compared to the area exposed to the edge $A = 2\pi r x$ to minimize energy loss. The energy transfer rate in the sample can be increased by keeping 'x' small and 'A 'large then the device quickly reaches a steady state.

Figure 4: Prepared disk with different layer to find Thermal conductivity.

Table 2: Average thickness and diameter of the samples

Layer	Average Thickness (x±0.01) mm	Average Diameter (d±0.05) mm	Average Mass (m±0.01) mm
1	0.17	4.20	1.23
2	0.80	4.45	2.68
3	3.48	4.80	4.65
4	3.50	4.50	5.65
5	4.80	4.40	6.60

(c) CHEMICAL REACTION TEST

Different acids were used to test the chemical reactivity in each layer as shown in Figure 5. Equal amounts and same concentration of Nitric acid (HNO_3), Sulfuric acid (H_2SO_4) and Hydrochloric acid (HCl) were collected in separate beakers and the samples were immersed in for 15 minutes. Observations were made every time. Although some chemicals react with the fiberglass samples, some do not.

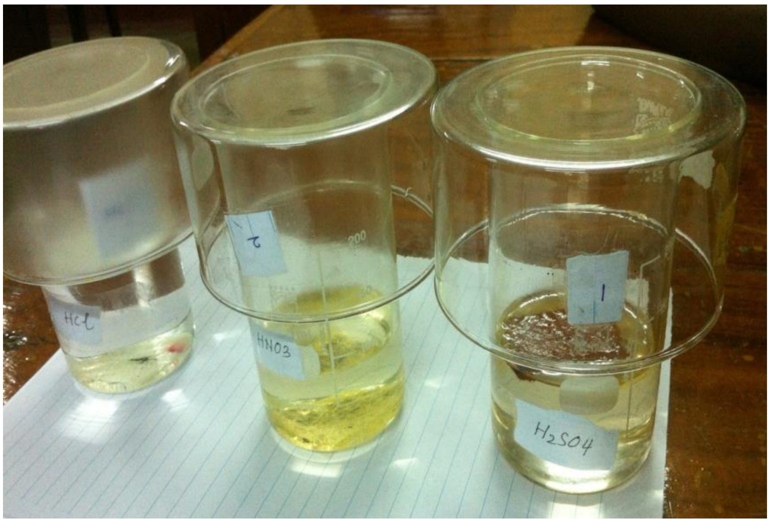

Figure 5: Chemical reactions observed for same conditions.

III. RESULTS AND DISCUSSIONS

The results are presented in tabular and graphical forms for Young's Modulus, Thermal Conductivity and Chemical reactions.

(a) YOUNG MODULUS

Table 3. Summarized readings for vibrating length and time period for the layers.

Layer 3		Layer 4		Layer 5	
Length (l±0.1) cm	***Time period (t±1/30) m***	***Length (l±0.1) cm***	***Time period (t±1/30) m***	***Length (l±0.1) cr***	***Time period (t±1/30 min***
40.0	3.0	38.5	3.0	42.0	2.9
41.0	4.0	39.5	3.3	43.0	3.0

42.0	4.2	40.5	3.5	44.0	3.1
43.0	4.5	41.5	4.0	45.0	3.2
44.0	4.8	42.5	4.1	46.0	3.5
45.0	5.2	43.5	4.2	47.0	3.7
46.0	5.5	44.5	5.2	-	-
47.0	5.8	45.5	5.5	-	-
-	-	46.5	6.3	-	-

*Layer 1 and Layer 2 is very thin layer and couldn't take the reading using Young's method.

The relationship between square of the period of oscillation and Cubic of vibrating length of the sample (Figure 6).

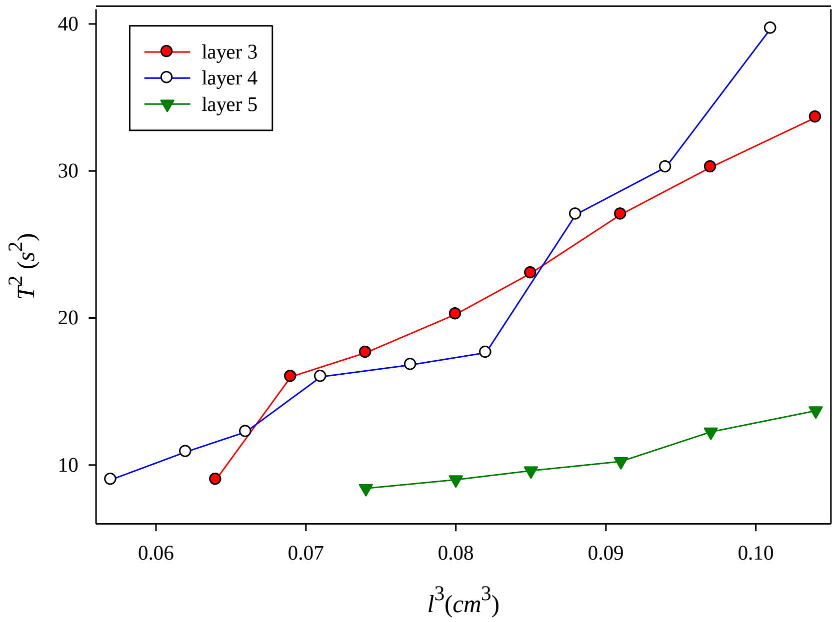

Figure 6: The vibrating length (l) dependence of time period (T) for the layers. The inset shows the expanded view of the l^3 versus T^3 lines. The gradient of the solid lines is inversely proportional to Young's Modulus of the layers.

(b) THERMAL CONDUCTIVITY

Table 4. The summarized details for steady state temperature and cool down time for Lee's disk method.

Layer	T_1 **(Θ±0.1)°C**	T_2 **(Θ±0.1)°C**	**Cool down Temperature**		**Time (min)**
			T_3	T_4	
1	40	50	34	37	16
2	38	46	32	35	15
3	36	42	32	33	15
4	34	38	32	33	16
5	32	34	32	32	15

Table 5. The summarized detail for Thermal Conductivity of the layers.

Layer	$k \times 10^{-6}\ (mm^{-1}s^{-1})$
1	3.84
2	21.43
3	35.61
4	57.31
5	175.40

Effect of Thickness on Thermal Conductivity of the sample

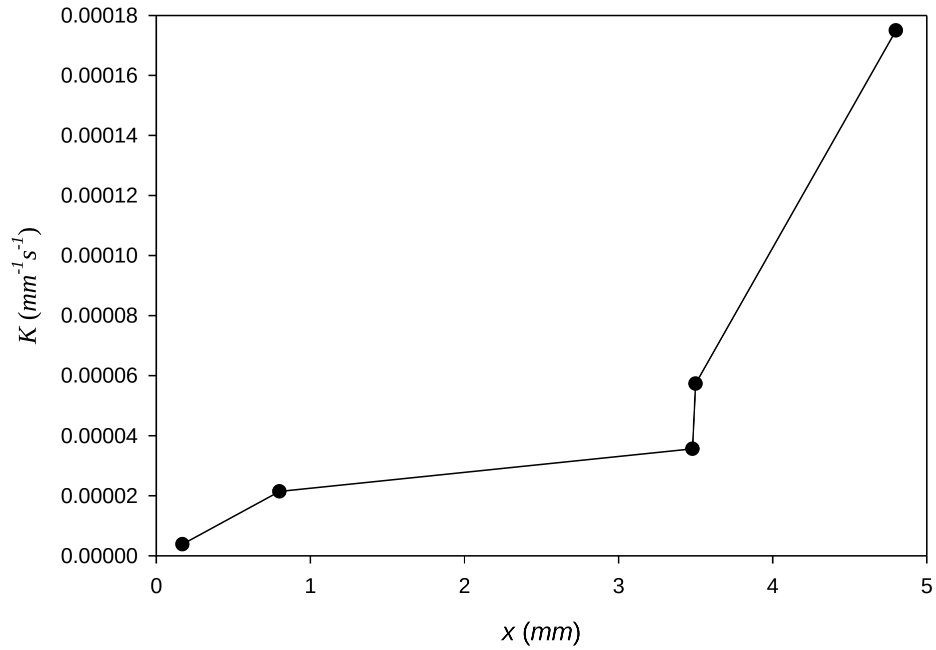

Figure 7. The black circles with solid line indicate the thickness dependence of Thermal Conductivity of the layers.

(c) CHEMICAL REACTION

Table 5.The summarized detail for chemical reaction of the layers.

Observations after 15 minuites			
Layer	**HNO_3**	**H_2SO_4**	**HCl**
01	Bubbles appeared Colour changed to light yellow	Bubbles appeared Colour changed to dark brown	Bubbles appeared No colour change
02	Bubbles appeared Colour changed to light yellow	Bubbles appeared Color changed to dark brown	Bubbles appeared No color change
03	No bubbles appeared No reaction observed	Bubbles appeared Colour changed to dark brown	Bubbles appeared No reaction observed
04	No bubbles appeared No reaction observed	No bubbles appeared Colour changed to dark brown	Bubbles appeared No reaction observed
05	No bubbles appeared No reaction observed	No bubbles appeared No reaction observed	No bubbles appeared No reaction observed

DISCUSSIONS

The properties of fiberglass with different layers depend on the amount of epoxy resin and a catalyst reinforced with a fiberglass mat.

Figure 6 shows that l^3 versus T^3 lines are increase with length of the sample. The slope of the solid line is inversely proportional to the Young's modulus of the layer. The Young's Modulus of the layers is increase with increasing the layers of the fiberglass. Because the mechanical bond between two objects, the surface energy bond and Vander Waals or electrostatic interactions or hydrogen bonds are effect the property of the fiberglass reinforced with the resin.

It was very difficult to read the experimental results, for layer 1 and 2 by vibration method because the sample was very thin and the sample become thicker when the number of layers increases more than five. Vibrating length should be enough to take reading; it was difficult for smaller lengths.

Figure 7 shows that the thermal conductivity of the layer depends on the fiberglass reinforced epoxy mat and increases with the thickness of the sample. Thermal conductivity of the layers is increase with increasing the layers of the fiberglass.

When the sample layer is less, some chemical reactions were occur but for higher values there are no chemical reactions for 15 minutes time interval. There may be more chemical reactions for long time interval and high concentration chemicals.

IV. CONCLUSIONS AND FUTURE SCOPE

Properties of all fiberglass and resin differ with the entire interface. Because of Vander Waals interaction and covalent bond between the fiberglass and epoxy resin, the properties of the layers are vary. Furthermore, this study extends to:

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

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