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Effect of Fiber Orientations on Thermal Properties of PALF Reinforced Bisphenol: A Composite

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Abstract:
Composites consist of two or more phases that are usually processed separately and then bonded, resulting in properties that are different from those of either of the component materials. Polymer matrix composites generally combine high-strength, high-stiffness fibers (graphite, kevlar, etc.) with low-density matrix materials (epoxy, polyvinyl, etc.) to produce strong & stiff materials that are lightweight,use of natural fibers as reinforcement in polymeric composites for technical application has been a research subject of scientist. Pineapple leaf fibre (PALF) is one of them that have also good potential as reinforcement in polymer composite. In this present work, an experimental study has been conducted to determine the effect of fiber orientation, namely, unidirectional, bidirectional and 45º orientation on thermal properties such as specific heat, thermal conductivity and thermal diffusivity of PALF reinforced Bisphenol-A (BPA) composite. This study shows, increase in specific heat and decrease in thermal conductivity and thermal diffusivity of Bisphenol-A resin after PALF reinforcement. Among three types of fiber orientation in composite, 45º orientation composite gives the best results.

***Keywords**: PALF, BPA, Alkaline treatment, Fiber orientations, Specific heat, Thermal conductivity, Thermal diffusivity*

1. Introduction

Now a day's polymeric materials are used in almost all the applications because of their specific characteristics such as light weight, self lubricancy and reduced noise. Natural fibers are advantageous over synthetic fibers as they are renewable, eco friendly, low in density, biodegradable and less abrasive. Thermal properties of a polymer composite is a function of resin type, fiber type and architecture, fiber volume fraction, direction of heat flow, and service temperature. Recognizing the thermal responses in Fiber Reinforced Polymer (FRP) composite decks play a critical role in their performance, accurate thermal measurements of FRP decks are essential. However, compared to mechanical properties, few investigations have been carried out with the thermal insulation property of natural fiber reinforced composites.

Pineapple Leaf Fibre (PALF) serving as reinforcement fibre in most of the plastic matrix has shown its significant role as it is cheap, exhibiting superior properties when compared to other natural fibre. PALF is multi-cellular and lignocelluloses materials extracted from the leave of plant Ananas cosomus belonging to the Bromeliaceae family by retting (separation of fabric bundles from the cortex). PALF has a ribbon-like structure and is cemented together by lignin material, which contribute to the strength of the fibre.

Bhyrav Mutnuri[1] studied the thermal conductivity characterization of composite materials. Ke Liu[2] studied the Effect of physicochemical structure of natural fiber on transverse thermalconductivity of unidirectional abaca/bamboo fiber composites. Maries Idicula[3] studied the thermophysical properties of natural fibre reinforced polyester composites. Xue Li[4]studied the thermal diffusivity, thermal conductivity, and specific heat of flax fiber–HDPE biocomposites at processing temperatures. R. Alavez-Ramirez[5] studied the thermal conductivity of coconut fibre filled ferrocement sandwich panels. M. Mounika[9] studied the thermal Conductivity Characterization of Bamboo Fiber Reinforced Polyester Composite. Therefore in the present work an attempt has been made to investigate the specific heat, thermal conductivity and thermal diffusivity of PALF reinforced Bisphenol-A composite.

2. Experiment

2.1. Materials
PALF extracted from the leaf of pineapple plant by biological method supplied from Chandra Prakash. Co, Jaipur, Rajastan. Bisphenol-A resin was supplied from Balaji fabrications, Mysore, Karnataka.

2.2. Chemical treatment of fiber
Alkali treatment or mercerization using sodium hydroxide (NAOH) is the most commonly used treatment for bleaching and cleaning the surface of natural fibers to produce high-quality fibers. 5% NaOH solution was prepared using sodium hydroxide pellets and distilled water. Pineapple leaf fibers were then dipped in the solution for 1hour. After 1 hour fibers were washed with 1% HCl solution to neutralize the fibers. Then it is washed with distilled water. It was then kept in hot air oven for 3hours at 65-70°c.

2.3. Preparation of composites and samples
All specimens in this study were manufactured by hand layup technique. The mould that was used is made of poly propylene with dimension ($100*70*10$ mm^3) is sown in the Figure 2.1. The chemical treated fiber yarns are woven in to unidirectional, bidirectional and 45 º orientational mats. The mould was filed by the mixture of Bisphenol-A resin and hardener (HY 951) of 10:1 ratio at room temperature. The mats (30% volume fraction) were added to mixture of resin and hardener. The load was applied to solidify, when the solidification process for all moulds is completed after 24 hours, the casts are released from the moulds. The composite laminates with different fiber orientation are shown in Figure 2.2. The composite were cut in to sample of c/s area $7.92\times10^{-2}m^2$ and thickness 6mm .

Figure 2.1 $100\times70\times10$ mm^3 mould

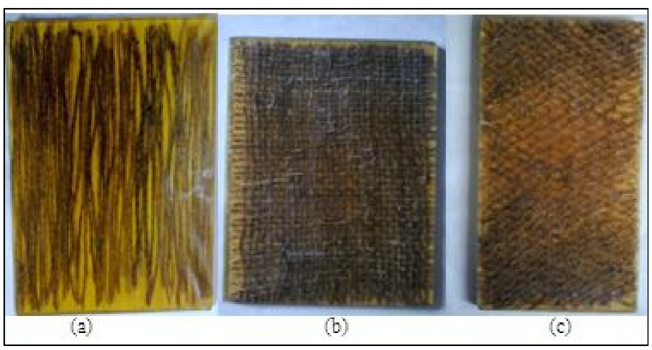

Figure 2.2: (a) Unidirectional (b) bidirectional (c) 45º orientational

2.4. Specific Heat
When heat flows into a substance, the temperature of that substance will increase. The quantity of heat required to cause a temperature change of any substance is proportional to the mass (m) of the substance and the temperature change(ΔT), the proportionality constant 'Cp' is called Specific heat.

$$q = C_p \times m \times \Delta T \qquad (2.1)$$

The specific heat can be considered to be the amount of heat required to raise the temperature of one gram of the substance by 1°C. Amounts of heat is measured in joules (historically: calories). The specific heat of water is 4.18 joules/g°C. Since 4.18 joules equals 1 calorie, we can also say that the specific heat of water is 1 calorie/g°C. Ordinarily heat flow into or out of a substance is determined by the effect that the flow has on a known amount of water. Because water plays such an important role in these measurements, the calorie, which was the unit of heat most commonly used until recently, was actually defined to be equal to the specific heat of water. The specific heat of a material can readily be measured in a calorimeter. A weighed amount of material is heated to some known temperature and is then quickly poured into a calorimeter that contains a measured amount of water at a known temperature. Heat flows from the material to the water, and the two equilibrate at some temperature between the initial temperatures of the material and the water.

The amount of heat that flows from the material as it cools is equal to the amount of heat absorbed by the water and the calorimeter.

For the heat flow q,

$q_{water} + q_{caloriemeter} = q_{composite}$ (2.4)

If we now express heat flow in terms of Equation 2.3 for both the water and the metal M, we get

$(C_p \times m \times \Delta T)_{water} + (C_p \times m \times \Delta T)_{caloriemeter} = (C_p \times m \times \Delta T)_{composite}$ (2.5)

In this experiment we measure the masses of water and metal and their initial and final temperatures. Given the specific heat of water, we can find the positive specific heat of the material by Equation 2.5.

Figure 2.3: Expiremental setup used to determine specific heat

2.5. Thermal Conductivity

Thermal conductivity is the property of a material to conduct heat. It can be defined as 'the quantity of heat transmitted through a unit thickness in a direction normal to a surface of unit area, due to a unit temperature gradient under steady state conditions'. Thermal conductivity was measured using a steady state method and perpendicular to fiber direction.The air duct is the housing where the component and the heating coil assembly has been placed is as shown in Figure 2.4. It is a rectangular passage made of galvanized iron sheet. It has a dimension of 150×100×600mm.

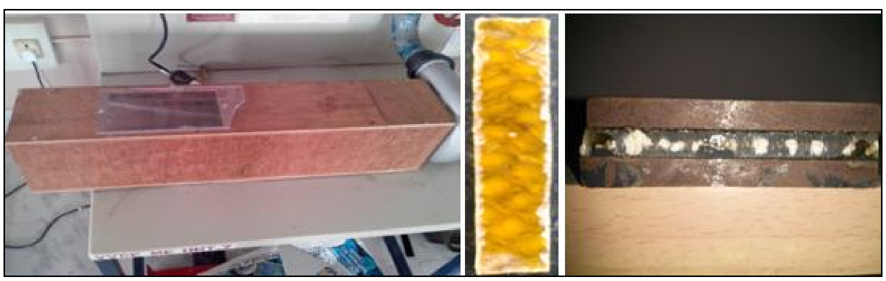

Figure 2.4: Expiremental setup used to determine specific heat(Air duct, specimen, sandwiched specimen)

The specimen was sandwiched between two mild steel plates and thermocouples were placed at the bottom, intermediate contact surfaces and at the top surface. Specimen was placed on the heating element and then the heating elements and thermocouples were plugged into the test rig. voltage was set at 50V and allowed for 20 minutes to reach steady state and then temperature readings from $T_o$to T_L were taken. Thermal conductivity is calculated using formaula:

$$Q = \frac{T_o \quad T_L}{\frac{L_1}{k_1 A_1} + \frac{L_2}{k_2 A_2} + \frac{L_3}{k_3 A_3}} \qquad (2.6)$$

Q= Heat transfer at steady state, T_o= Base temperature, T_L= Surface temperature, L_1=L_3 Thickness of the known material, L_2= Thickness of the specimen, k_1=k_3= Thermal conductivity of known material, k_2= Thermal conductivity of specimen, A_1=A_3= Surface area of the known material, A_2= Surface area of the specimen

2.6. Thermal diffusivity

Thermal diffusivity is a material-specific property for characterizing unsteady heat conduction. This value describes how quickly a material reacts to a change in temperature. It is the thermal conductivity divided by density and specific heat capacity at constant pressure. It measures the ability of a material to conduct thermal energy relative to its ability to store thermal energy. It has the SI unit of m²/s.An attempt was made to theoretically calculate thermal diffusivity of PALF reinforced Bisphenol composites using the equation -2.7.

$$\alpha = \frac{k}{\rho . C_p} \qquad (2.7)$$

α= Thermal diffusivity, k= thermal conductivity, ρ= density, C_p= specific heat

3. Results and Discussion

The specific heat of unreinforced resin and PALF reinforced composite is tabulated in the Table 3.1. From the table it can be observed that, the specific heat of Bisphenol-A resin is 3132.17 J/Kg.k and this is increased by 5.40%, 5.48% and 5.52% after reinforcement by unidirectional, bidirectional and 45º orientation fiber orientations respectively. The reason for increased specific heat of PALF reinforced composite may be the heat insulation ability of the fibers. The point to be noted is, there is no significant difference in specific heat existed between 3 types of composite, which indicates that fiber orientation has no effect on specific heat. Figure 3.1 shows variation of Resin and fiber orientations in composite v/s specific heat.

Thermal conductivity with respect to different fiber orientations is tabulated in Table 3.1. Figure 3.2 shows the thermal conductivity for resin & different fiber orientation for PALF composite .It is observed that the thermal conductivity of unidirectional, bidirectional and 45º orientation composite is 1.219, 0.869 and 0.858 W/m.k respectively. The thermal conductivity of unreinforced resin is 1.381 and the conductivity decreased by 11.73%, 37.07% and 37.87% after reinforcement by unidirectional, bidirectional and 45º fiber orientation respectively. The thermal conductivity of 45º composite is 29.61% less than the unidirectional composite and 1.26% less than the bidirectional composite. The reason for decrease in thermal conductivity after PALF reinforcement is insulation ability of the fibers. Less thermal conductivity in 45º orientation and bidirectional fiber composites has existed due to tightness of mat of fiber yarn and presence of heterogeneity. The point to be noted is, no appreciable difference in thermal conductivity has existed between bidirectional and 45º orientation fiber composite. The changes in thermal conductivity with respect to different fiber orientation clearly indicates that, orientation of fibers in composite have significant effect on thermal conductivity.

The thermal diffusivity of composite with different fiber orientation is tabulated in Table 3.1. Figure 3.3 shows the variation of thermal diffusivity for the resin & different fiber orientation for PALF composite. It was observed that the thermal diffusivity of pure resin was $3.1106*10^{-7}$ m^2/s, which was 8.86%, 36.79% and 60.44% lesser than composite with unidirectional, bidirectional and 45ºorientation fiber orientations respectively. The decrease in thermal diffusivity indicates the insulation ability of composite.

Sl. no	Specimen	Specific heat (J/kg.k)	Thermal conductivity(W/m.k)	Thermal diffusivity (m^2/s)
1	Bisphenol-A	3512.17	1.381	$3.1106*10^{-7}$
2	Unidirectional	3712.97	1.219	$2.8349*10^{-7}$
3	Bidirectional	3716.15	0.869	$1.9661*10^{-7}$
4	45º orientation	3717.52	0.858	$1.2303*10^{-7}$

Table 3.1: Expiremental results of thermal properties

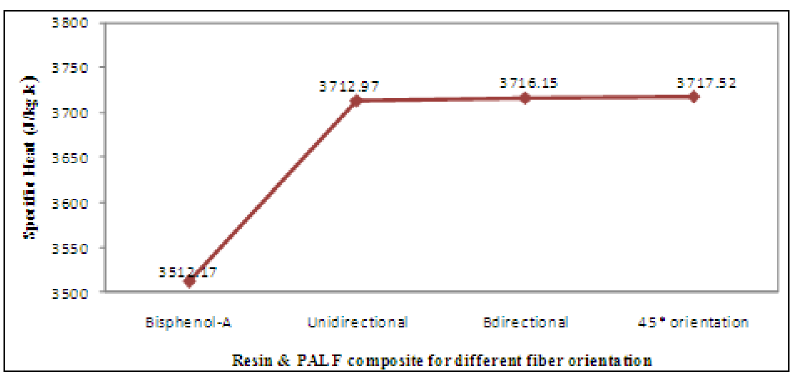

Figure 3.1 Specific heat for the resin & PALF composite for different fiber orientation

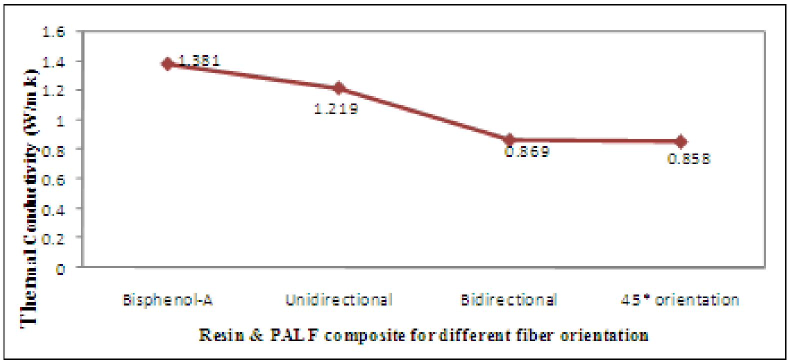

Figure 3.2 Thermal conductivity for resin & PALF composite for different fiber orientation

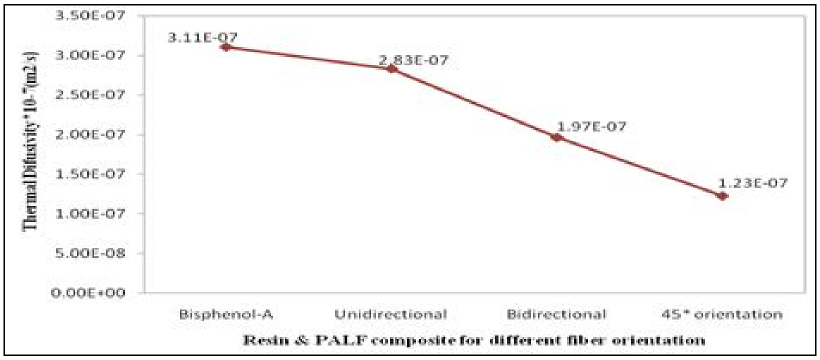

Figure 3.3 Thermal diffusivity for the resin & PALF composite for different fiber orientation

4. Conclusion

The properties such as specific heat, thermal conductivity and thermal diffusivity of unreinforced Bisphenol-A resin and fiber composite are studied. Specific heat of unreinforced Bisphenol-A resin increased after reinforcement of fiber due to insulation ability of fibers. All the three types of fiber composite improved the specific heat but there is no significant difference in their specific between them. This indicated that fiber orientation has no effect on specific heat. In the study of thermal conductivity, the thermal conductivity of unreinforced Bisphenol-A resin decreased after reinforcement by fiber. 45º orientation fiber composite shown the least thermal conductivity out of three types of fiber composite. There is no significant difference in thermal conductivity observed between bidirectional and 45º orientation fiber composite. The decrease in thermal conductivity may be due to tightness of weave and presence of heterogeneity in the composite. Thermal diffusivity of composite is same as that of the thermal conductivity, thermal diffusivity of unreinforced Bisphenol-A resin decreased after fiber reinforcement and thermal diffusivity for 45º orientation fiber composite is less compared to that of unidirectional and bidirectional composite. The decrease in thermal diffusivity indicated the material ability to resist the increase in temperature.

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