Fabrication and Thermal Analysis of Sisal Banana Epoxy Composite Size

S.Sakthivel[1] K.Sivanantham[2] R.Ramesh[3] S.Sasidharan[4]
[1,2,3,4]Assistant Professor
[1,2,3,4]Department of Mechanical Engineering
[1,2,3,4]Muthayammal Engineering College, Rasipuram, Namakkal, Taminadu, India

Abstract— Thermal properties of a polymer composite is a function of resin type, fiber type, architecture, fiber volume fraction, direction of heat flow and service temperature. The thermal response of Fiber Reinforced Polymer (FRP) composites plays a critical role in their performance. The objective of this project is to attain better understanding of thermal behavior of a composite structural system through fundamental understanding of thermal behavior conductivities properties and thermal stability. In this project Natural fiber composites were fabricated by hand layup process. LY556 resin and HY951 hardener mixed in the ratio 10:1 was used as matrix. Composites were fabricated using hybrid mixture of sisal and banana. The effective thermal conductivity is determined by using rule of mixtures. The thermal stability was determined by TGA/DTA techniques. Among the fabricated composites, samples with 13% sisal and 11% banana shows higher thermal stability. The sample with sisal 13% and banana 11% showed least thermal conductivity.

Key words: Thermal Stability, Thermal Conductivity, Banana fibre, FRP

I. INTRODUCTION

The Processing of plastic composites using natural fibres as reinforcement has increased dramatically in recent years. The advantage of composite materials over conventional materials stem largely from their higher specific strength, stiffness and fatigue characteristics, which enables structural designs to be more versatile. By definition these composite materials are engineered or naturally occurring materials made from two or more constituents materials with significantly different physical or chemical properties which remain separate and distinct at macroscopic and microscopic scale within the finished structure.

Increasing use of composites for various applications emphasizes its importance / significance in the thermal property analysis of an engineering system. Thermal property of a composite combination of two or more constituents can be measured by experimental methods. Analytical equations are essential to predict thermal properties of composite materials would fabricate the design of an engineering system made of FRPs. Published literature is rich with investigation of mechanical properties of composites. Fewer publications focused on the thermal properties. Several publications, Muralidhar (1989), Springer and Tsai (1967) addressing different theoretical approaches for predicting thermal conductivity of composite materials have been noted. However, one of the publications Gowayed, (1995) has discussed both transverse and axial thermal conductivity of a carbon fibre composite. A non–linear increase in the thermal conductivity was reported with the increase of fiber volume fraction of plain weaves and no theoretical models are able to predict this non– linearity . The result of literature search even further identified the necessity and importance of carrying out the proposed research. This review is focused on: 1) The concept of thermal properties, 2) Experimental methods for measuring them, 3) Analytical / Numerical methods for predicting thermal properties.

C. Parida, et al was done the paper deals with the effect of fiber treatment on tensile, flexural, compressive properties as well as thermal degradation of LC fibers – reinforced resorcinol formaldehyde composite. To overcome the problem of poor adhesion between hydrophilic fiber and hydrophilic matrix, LC fibers were subjected to three treatments such as alkali treatment, bleaching and acid hydrolysis. As a result of these treatments the fibers became more crystalline hence there was an increase in the fiber matrix adhesion. Due to the increase in adhesion there was an increase in the thermal stability. For instance during TGA, composites with untreated fibers had a mass loss of 37 % at 400°C but for composites with treated fibers the mass loss was only 32%. The paper mainly deals with the mechanical properties of the composites. The thermal evaluation was limited to the determination of the thermal stability by Thermo gravimetric Analysis. The paper is silent on other thermal properties like thermal conductivity, heat capacity.

Valcineide O. A. Tanobea, et al was done this work, different chemical treatment were conducted on the fibers with aqueous solutions of NaOH 2% or methacrylamide (1-3 %) at distinct treatment times . The paper mainly deals with the properties of fibers due to chemical treatment and there was only a slight increase in the thermal stability of the fibers as a result of the chemical treatment. The fibers in the work are reported to have undergone significant thermal damage before reaching 250°C. But however from the previous paper it is evident that by combining the fibers and the epoxy a more thermally stable material is produced than pure fibers. The increase in the thermal properties is due to better adhesion between the fibers and the resin, requiring more thermal energy for the degradation. Similar to the previous paper this paper is silent on other thermal properties like thermal conductivity, heat capacity.

Sudhir Kumar Saw, et al in this work, two chemical treatments, alkalization (2h agitation with 5% NaOH) and furfurylation (graft furfuryl alcohol followed by oxidation with (1N) NaClO2 solution) were conducted on luffa cylindrical fiber surfaces. The grafting of furfuryl alcohol followed by oxidation generated quinines showed better results than alkaline treatment with respect to enhancement of surface area and hydrophobicity as well as wax, lignin and hemicellulose extraction. The efficiency of chemical treatments was verified by elemental analysis and FTIR spectroscopy. Differential scanning Calorimetery, thermo-gravimetric analysis, Scanning electron microscopy, Water absorption and mechanical tests were performed to determine the thermal, mechanical and morphological

properties of untreated and chemically treated Luffa fiber reinforced epoxy composites.

Mehmet Akgul et al this study was conducted to evaluate suitability of luffa (luffa cylindrical) fiber for medium density fiberboard (MDF) production. For the experiment, luffa and commercially manufactured fibers (Pinus sylvestris (30%), Fagus orientallis Lipsky (35%) and Quercus robor L (35%) with 11% moisture content were used. Luffa was mixed with commercially manufactured fibers in the following fashion : a layer of luffa fiber (30 g) placed in the middle of the mat , two equidistantly placed layers (60 g) in the mat , three layers (90 g) instead of two in the mat , and homogenously (90 g) dispersed without a distinct pattern in the mat respectively . In panel production the only variable tested was the addition of luffa fiber at various weights to the wood fibers. Commercial urea formaldehyde (UF) adhesive used as a binder. Chemical properties, including holocellulose and contents, alcohol – benzene solubility in dilute alkali (1% NaOH) and hot and cold water stability were determined . In addition , some physical and mechanical properties such as density , thickness swelling (TS) , bending strength (BS) , modulus of elasticity (MOE) and internal bond (IB) of the panel of MDF were also measured . The chemical composition and solubility of luffa were found to be similar to those of non woods in general. Thus the results suggest that luffa (luffa cylindrical Mill) fiber can be used as an alternative raw material for MDF manufacturing

II. Theoretical Approach for Thermal Conductivity Predictions

The theoretical approach brings more generalized equation for a two dimensional steady state heat flow. Various theoretical approaches are used to yield the thermal conductivity of a composite material so that the heat flow in a anisotropic composite material in any direction can be estimated.

Barbero et al the rule of mixture and finite difference method for homogenous fibers of thermal conductivity Kf embedded in a resin matrix of thermal conductivity Km, the thermal conductivity Kp parallel to the axis of the fiber is given by (Barbero, 1998)

$$Kp = KfVf + (1 – Vf) Km \quad (1)$$

Where Vf is the fiber volume fraction while the thermal conductivity in transverse direction (Kt) can be given as

$$1 / kt = Vf / Kf + (1 – Vf) Km \quad (2)$$

James et al However, Equation (2) developed by rule of mixtures gives the lower limit value of the transverse thermal conductivity. The upper limit value can be give as (James et al, 1987)

$$Kt = BKm (1 - Vf) + (Vf + (1 – B) (1 – Vf) KfKm) / (VfKm + (1 – B) (1- B) (1- Vf) Kf) \quad (3)$$

In finite difference method the body in which the heat flows occurs is divided into equal increments in both x, y directions creating nodal points in both the directions. According to the finite difference method the temperature around the nodal point is related to the thermal conductivity for the material link between the nodes as

$$Ti = (j = 1,4 KjTj) / (j + 1,4Kj) \quad (4)$$

Where Kj is the thermal conductivity between the nodes. Equation (3) is applied sequentially to all nodes of a body using the latest calculated valves and the process is repeatedly until a steady state equation is obtained by Gauss - Seidel iteration.

Caruso et al A general finite element analysis method was proposed by Carso et al (1986) to predict thermal conductivity of a composite. This method is based on integrating Advanced Finite Element Methods with simplified Micromechanics equations. The boundary conditions and loading conditions i.e. change in temperature and thermal expansions were considered in the derivations of equations to predict the thermal conductivity. The longitudinal and transverse conductivity equations were given as

$$KL = Vf * Kfl = Vm Kml \quad (3)$$

$$Kt = (1- \times km) + \quad (4)$$

Where KL is the thermal conductivity in longitudinal direction of fiber and matrix respectively.

Dr. Thomas G. Schuh This paper deals with the applications of the various natural fiber reinforced composites and the importance of why such materials should be used in the automotive industries. One of the major reason for this renewed growth is an increased awareness for our environment, reflected in phrases such as " protection of resources " , " reduction of CO2 emissions " , and " recycling " . Plant fibers are currently only used in the interior of passenger cars and truck cabins. Besides their use in trim parts such as door panels or cabin linings, plant fibers are used extensively for thermo-acoustic insulation.

Even though a large number of literatures are available on Luffa epoxy reinforced composites a few deal with their thermal properties most journals concentrate on their mechanical properties. In order to perform the thermal analysis on Luffa composite certain basic data were required which are taken from the available literature and user manuals .TGA and DSC measurements by various authors indicate that the degradation of these materials will take place at temperature in the range of 200 to 250 °C, which implies the Service temperature of these materials is less than 200 °C. It is found that composites with better mechanical properties and one which can withstand high temperature can be produced if fibers are alkali treated.

III. Materials and Treatment

Sisal with the botanical name Agave sisalana is a species of Agave native to southern Mexico but widely cultivated and naturalized in many other countries. It yields a stiff fibre used in making various products. The term sisal may refer either to the plant's common name or the fibre, depending on the context. It is sometimes referred to as "sisal hemp", because for centuries hemp was a major source for fibre, and other fibre sources were named after it. The sisal fibre is traditionally used for rope and twine, and has many other uses, including paper, cloth, wall coverings, carpets, and dartboards.

Fig. 1: Sisal Fibers

A. Composition of Sisal

Sisal is composed of many chemical components. Cellulose is the main component of sisal fiber. Here the composition of sisal fiber is shown in below table

Characteristic property	Inferences
Cellulose	71.5%
Hemi cellulose	18.1%
Fat and wax	0.5%
Lignin	5.9%
Pectin	2.3%
Soluble matter	1.7%

Table 1: Chemical Properties of Sisal fiber

Characteristic property	Inferences
Density	1.5 gm/cc
Flexural modulus	12.5 – 17.5
Tensile strength	68 Mpa
Young's modulus	3.774
Diameter	100 – 300 (μm)
Thermal conductivity	0.07 W/m-K

Table 2: Physical Properties of sisal fiber

B. Banana Fiber

Banana fiber is a natural bast fiber. It has its own physical and chemical characteristics and many other properties that make it a fine quality fiber. Banana fiber is extracted from the pseudo stem Sheath of the plant. The extraction can be done mainly in three ways: Manual, chemical and Mechanical. Of these, mechanical extraction is the best way to obtain fiber of both good quality and quantity in an eco-friendly way. In this process the fiber is extracted by inserting the pseudo stem sheaths one by one into a raspador machine. The raspador machine removes non-fibrous tissues and the coherent material (known as sctcher) from the fiber bundle present in the sheath and gives the fine fiber as output. After extraction, the fiber is shade dried for a day and packed in HDPE bags. Then extraction, then it is stored away from moisture and light to keep it in good condition until it is used.

It is highly strong fiber and has smaller elongation. It has somewhat shiny appearance depending upon the extraction & spinning process. It is light weight. It has strong moisture absorption quality. It absorbs as well as releases moisture very fast. It is bio- degradable and has no negative effect on environment and thus can be categorized as eco-friendly fiber. It can be spun through almost all the methods of spinning including ring spinning, open-end spinning, bast fiber spinning, and semi-worsted spinning among others.

Fig. 2: Banana Fiber

C. Composition of Banana Fiber

The chemical composition of banana fiber is determined by elemental analysis.

Characteristic property	Inferences
Cellulose	31-35%
Hemi cellulose	14-17%
Lignin	15-16%

Table 3: Chemical Properties of banana fiber

Characteristic property	Inferences
Density	1.3 gm/cc
Compressive strength	12.5 – 17.5 Mpa
Tensile strength	49.85 Mpa
Diameter	50 – 250 (μm)
Thermal conductivity	0.09 W/m-K

Table 4: Physical Properties of banana fiber

D. Epoxy Resin

Epoxy or polyoxide is a thermosetting polymer former reaction of an epoxide "resin" with "polyamine" hardener. Epoxy has a wide range of applications including fiber-reinforced plastic materials and general purpose adhesives.

IV. Fabrication of Composites

In this project we are doing 3 different types of mould specimen.

- 18% sisal + 6% banana
- 15% sisal + 9% banana
- 13% sisal + 11% banana

A. Weight Calculation

Volume of plate = l * b * t
Volume = 30 * 30 * 0.3
Volume = 270 cm^3
Total volume of plate = 270cm^3
Density of sisal = 1.5gm/cm^3
Density of banana = 1.3gm/cm^3
Density of resin = 1.02gm/cm^3
Volume fraction = volume of plate * % volume of fibre
Weight = volume fraction * density

1) Specimen A [18% sisal + 6% banana]

Here 18 % of sisal and 6 % of banana is taken for mould preparation.

a) Volume

$$18\ \%\ \text{of sisal} = \frac{270 * 18}{100} = 48.6\ cm^3$$

$$6\ \%\ \text{of banana} = \frac{270 * 6}{100} = 16.2\ cm^3$$

$$76\ \%\ \text{of resin} = \frac{270 * 76}{100} = 205.2\ cm^3$$

b) Weight

48.6 cm^3 of sisal = 48.6 * 1.5 = 72.9 g
16.2 cm^3 of banana = 16.2 * 1.3 = 21.06 g
205.2 cm^3 of resin = 205.2 * 1.02 = 209.3 g
Total weight of plate = 72.9 + 21.06 + 209.3 = 303.26g

2) Specimen B [15% sisal + 9% banana]

Here 15 % of sisal and 9 % of banana is taken for mould preparation.

a) Volume

$$15\ \%\ \text{of sisal} = \frac{270 * 15}{100} = 40.5\ cm^3$$

$$9\ \%\ \text{of banana} = \frac{270 * 9}{100} = 24.3\ cm^3$$

$$76\ \%\ \text{of resin} = \frac{270 * 76}{100} = 205.2\ cm^3$$

b) Weight

40.5 cm3 of sisal = 40.5 * 1.5 = 60.75 g
24.3 cm3 of banana = 24.3 * 1.3 = 31.59 g
205.2 cm3 of resin = 205.2 * 1.02 = 209.3 g
Total weight of plate = 60.75 + 31.59 + 209.3 = 303.2g

3) Specimen C [13% sisal + 11% banana]

Here 13 % of sisal and 11 % of banana is taken for mould preparation.

a) Volume

$$13\ \%\ \text{of sisal} = \frac{270 * 13}{100} = 35.1\ cm^3$$

$$11\ \%\ \text{of banana} = \frac{270 * 11}{100} = 29.7\ cm^3$$

$$76\ \%\ \text{of resin} = \frac{270 * 76}{100} = 205.2\ cm^3$$

b) Weight

35.1 cm^3 of sisal = 35.1 * 1.5 = 52.65
29.7 cm^3 of banana = 29.7 * 1.3 = 38.61 g
205.2 cm^3 of resin = 205.2 * 1.02 = 209.3 g
Total weight of plate = 52.65 + 38.61 + 209.3 = 303.26 g

Specimen A Specimen B Specimen C

Fig. 3: Specimens

V. Determination of Thermal Conductivity

The theoretical approach brings more generalized equation for two dimensional steady state heat flows.

Various theoretical approaches are used to yield the thermal conductivity of a composite material so that the heat flow in anisotropic composite material in any direction can be estimated. Generally used formulae for the theoretical prediction of thermal conductivity is the rule of mixtures formulae which gives

$$K_{eff} = \frac{V1}{100} \times K1 + \frac{V2}{100} \times K2 + \frac{V3}{100} \times K3$$

Where

V1, V2, V3 are percentage volume of constituents

(V1+V2+V3 = 100)

K1, K2, K3 are thermal conductivity of the constituents. Keff is the thermal conductivity of the composite.

A. Sample 1

V1 = 18 K1 = 0.19 (W/mK)
V2 = 6 K2 = 0.09 (W/mK)
V3 = 76 K3 = 0.363 (W/mK)
Keff = 0.012+0.0054+0.27588
Keff = 0.328 (W/mK)

B. Sample 2

V1 = 15 K1 = 0.19 (W/mK)
V2 = 9 K2 = 0.09 (W/mK)
V3 = 76 K3 = 0.363 (W/mK)
Keff = 0.0105+0.0081+0.27588
Keff = 0.313 (W/mK)

C. Sample 3

V1 = 13 K1 = 0.19 (W/mK)
V2 = 11 K2 = 0.09 (W/mK)
V3 = 76 K3 = 0.363 (W/mK)
Keff = 0.0247+0.0099+0.27588
Keff = 0.311 (W/mK)

Among the three composites, the composite with sisal 13% and banana 11% has low thermal conductivity. The thermal conductivity of the hybrid composite increases with increase of banana fiber in the composites. The decrease of banana fiber affects the thermal conductivity of the composite.

VI. Thermogravimetric Analysis

The Thermo gravimetric Analyzer (TGA) is an essential tool used for material characterization. TGA is used as a technique to characterize materials used in various environmental, food, pharmaceutical and petrochemical applications. Thermo gravimetric Analysis is a technique in which the mass of a substance is monitored as a function of temperature or time as the sample specimen is subjected to a controlled temperature program in a controlled atmosphere. An Alternate Definition, TGA is a technique in which upon heating a material, its weight increases or decreases. TGA measures a sample's weight as it is heated or cooled in a furnace. A TGA consists of a sample pan that is supported by a precision balance. That pan resides in a furnace and is heated or cooled during the experiment. The mass of the sample is monitored during the experiment. A sample purge gas controls the sample environment. This gas may be inert or a reactive gas that flows over the sample and exists through an exhaust. The abscissa (X-axis) can be displayed as time or temperature and the co-ordinate (Y-axis) can be displayed as weight (mg) or weight percent (%). A TGA thermal curve is displayed from left to right. The descending TGA thermal curve indicates a weight loss occurred

VII. Results of TGA/DT Analysis

The TG/DT analysis for this project was carried out on Shimadzu TGA 50. The temperature range was from room temperature to 30-35 °C and the heating rate was 10 K / min. The atmosphere was nitrogen atmosphere. The samples were in quantities of 6 mg in powder form. The crucible used for the analysis was alumina crucible. The samples were powdered and were sealed in an air tight bag and were given to analysis. The residual mass after the analysis was 10 % of initial mass.

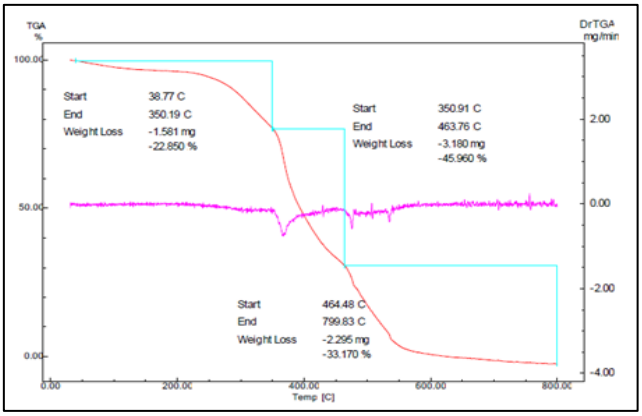

Fig. 4: TGA Curves for Sample 1

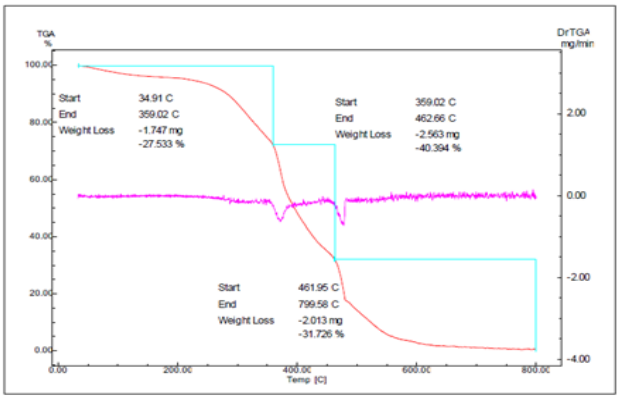

Fig. 5: TGA Curves for Sample 2

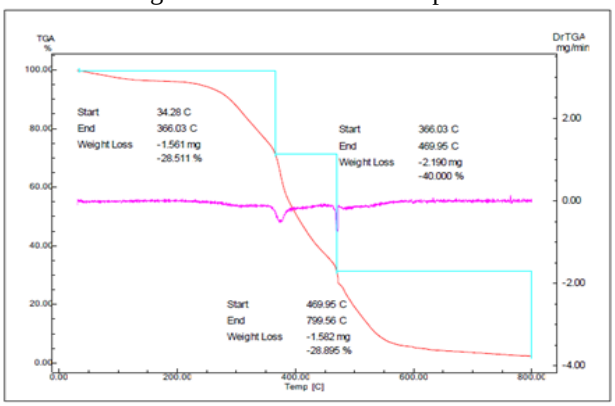

Fig. 6: TGA Curves for Sample 3

Among the three composites, the composite with sisal 13% and banana 11% has higher thermal stability. The thermal stability of the hybrid composite increases with increase of banana fiber in the composites. The decrease of banana fiber affects the thermal stability of the composite.

VIII. Conclusion

Based on the investigation on the fabrication of sisal banana epoxy based composites, it can be concluded that Different sets of sisal banana epoxy based composites can be successfully fabricated by simple and lay-up technique for different volume fraction of fibers. The rules mixtures show that the effective thermal conductivity can be easily determined by calculating the volume fraction and thermal conductivity of the constituents. The thermal stability of the composite is easily determined by using the TGA/DTA technique by using the powder of the fabricated composite. With light weight and reduced heat conductivity, these fiber reinforced polymer composites finds their potential applications in insulation boards, food containers, thermo flasks, building material etc.

References

[1] C. Parida , S K Das , "Effect of fiber treatment on mechanical and thermal properties of Luffa Cylindrica - Resorcinol Composites", International Journal of Fiber and Textile Research
[2] Valcineide O. A Tanobea , Thais H.D Sydenstrickera, Marilda Brazilian Sponge – Gourds (Luffa cylindrical), Polymer Testing 24 (2005) 472-482, www.elsevier.com/locate/polytest
[3] Sudhir Kumar Saw, Raghwendra Purwar, Sourabh Nandy, Joyjeet Ghose and Gautama Sarkel, Fabrication, "Characterization and Evaluation of Luffa Cylindrica Fiber Reinforced Epoxy Composites" www.Biosources.com, Augest 2013
[4] Maya Jacob John, Bejoy Francis, K .T. Varughese, Sabu Thomas, "Effect of chemical modification on properties of hybrid fibers biocomposites", www.elsevier.com/locate/compositesa
[5] Mei-po H O, Hao Wang , Joong – Hee Lee , Chun – kit Ho, Kin – tak Lau , Jinsong Leng , David Hui, "Critical factors on manufacturing processes of natural fibre composites", www.elsevier.com/locate/compositesb
[6] S.V. Joshi, L.T. Drazel , A.K. Mohanty , S. Arora . Are "Natural Fiber Composites environmentally superior to Glass Fiber reinforced Composites" www.elsevier.com/locate/compositesa
[7] "Journal of brazillian society for Natural Fibers" www.scielo.br/scielo.php?pid=51678-58782006000100005
[8] Yagya Kumar Sahu. "Study of effective thermal conductivity of Fiber Reinforced Epoxy composites".
[9] Dr. Mathew R Hall. "Materials for energy efficiency and Thermal comfort in Buildings."

