International Journal Of Advance Research, Ideas And Innovations In Technology

ISSN: 2454-132X
Impact Factor: 6.078
(Volume 9, Issue 2 - V9I2-1151)
Available online at: https://www.ijariit.com

# Investigation on thermal conductivity of polymer (epoxy) based composites

*Suhas B. R.*
suz_794@yahoo.com
*Dayananda Sagar College of Engineering, Bengaluru, Karnataka*

*Manjunath S. B.*
manjunathsb-me@dayanandasagar.edu
*Dayananda Sagar College of Engineering, Bengaluru, Karnataka*

## ABSTRACT

***The current research investigates the influence of fiber volume fraction on effective thermal conductivity (keff) in polymeric materials. This study identifies a method to improve the insulating property of a traditional fiber-reinforced polymer composite. A quantitative relationship for the heat transfer coefficients of polymer composites reinforced with fiber is created utilizing the law of minimal thermal performance and the equal law of particular similar thermal conductivity. To validate this statistical equation, two sets of polymer composites with fiber concentrations ranging from 0 to 15.7 vol percent were hand-built. Natural fibers such as banana fibers are integrated into an epoxy matrix in one set of composites, whilst glass fiber is employed as a filler material in another set, although the matrix material remains unchanged. Thermal conductivities of these composite materials are tested in accordance with ASTM standard E-1530 using the Unit herm TM Model 2022 tester, which operates on the double shielded heat flow concept. Furthermore, using the commercially accessible finite element tool ANSYS, the finite element technique (FEM) is employed to quantitatively measure the k eff of such composites. The numerical values generated by the proposed statistical model are then compared to empirically measured values. The analytical and simulation results reveal that the appropriate heat conductivity value for both sets of composites steadily declines as fiber concentration increases. Because none of the models developed properly anticipated the rate of heat transfer of the composites, the results generated from the proposed system closely match the experimental data. This study shows that as the fiber loading in the composite increases, so does the heat transmission rate. The use of 15.7 vol percent glass fiber in epoxy resin reduces heat conductivity by around 8%, whereas a 12 percent decrease is observed when the banana fiber is used as a filler. This research backs up the conceptual approach while indicating that finite element analysis is an effective tool for such investigations. This thermal insulating, fiber-reinforced polymer composites have potential applications in insulating boards, food containers, thermo flasks, construction materials, and so on due to their low thermal conductivity and lightweight.***

**Keywords:** *Thermal Conductivities Filler, Matrix*

## 1. INTRODUCTION

Background and Motivation
Requirement of Thermal Insulation

It is critical for human and animal convenience and, in some situations, life to slow the transfer of heat by utilizing an insulating medium. Insulation offers many advantages in industry, such as preventing damage from freezing of different goods or damage from elevated heat, and lowering heating and cooling costs. Heat moves in just one axis from a hot body to a cool (i.e. less warm) body, hence insulation helps to reduce this flow. Coating, for example, reduced the heat movement from the room air to the inside of the freezer. Insulation in a structure that keeps out heat during the summertime and in during the wintertime.

Construction materials that really are excellent insulators naturally are utilized to protect structures. Buildings can also be shielded by leaving gaps in the walls and ceilings and filling the gaps with a protective substance. Snow blocks used in Eskimo igloos, straw used in thatched roofs, and sunbaked clay homes in Northern part of Africa, East (Middle), and Latin America all provide excellent insulation.

Insulation materials are usually available as loose fills or as batts backed with foil or paper. They are set up amongst the internal and external walls as well as in the attic floor or ceiling. Weather stripping around the frame and the installation of storm windows and storm doors help to insulate windows and doors.

Glass fiber, nylon, carbon fiber, and other synthetic fibers are being examined as viable filler materials for a variety of applications such as wear resistance and structural components. Glass fiber - reinforced polymer matrix composites are essential engineering components due to their low density and high specific stiffness and strength. Because of its poor thermal conductivity, this synthetic fiber has been identified as a suitable filler for increasing the insulation capabilities of various polymers.

However, these synthetic fibers reinforced polymer composites have some drawbacks, like being corrosive and poisonous in nature, being more expensive, and being non-recyclable.

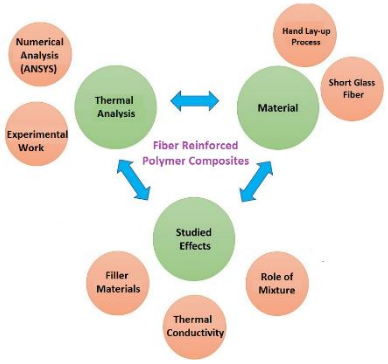



**Figure 1: Graphical Abstract**

It is notable that natural fibers such as sisal, jute, coir, husks, banana, and so on are abundant but underutilized. At the moment, these fibers are used to make mats, cables, threads, and matting, and also elegant items like table mats, handbags, wall hangings, and purses. Cotton, banana, and pineapple are all used in the textile business in relation to the paper sector. Natural fiber reinforced composites have attracted much attention in recent generations as ecological sensitivity and environmental awareness have grown. Composites have massive benefits, including minimal price, light weight, nontoxicity, biodegradability, and so on. Previously, organic fillers such as pineapple, coconut and arecanut, coir, sisal, and others were used as reinforcements in composites. Aside from that, natural fibers have a far good thermal conductivity than man - made fibers and can be utilized as a filler in a variety of insulating applications. As a result, there has been an emphasis on developing a type of light, porous material with enhanced mechanical properties such as strength insulating capabilities. Against such an environment, polymer composites developed as a potential engineering insulating material.

## 2. OBJECTIVE OF THE PRESENT INVESTIGATION

The objectives of this work are outlined as follows:

- A theoretical model is constructed to estimate the effective thermal conductivity of fiber reinforced composites.
- sets of epoxy-based composites were created to validate this mathematical model.
- In one set of composites, a well-known synthetic fiber, namely glass fibers, is integrated in an epoxy matrix, whereas in another set, a low-cost natural fiber, namely banana fiber, is used as a filler material, while the matrix material stays unchanged.
- The study's goal is to improve the thermal insulation properties of fiber reinforced polyester composites while lowering the effective thermal conductivity of the composite system.
- Experimentation with measuring the effective thermal conductivity (Keff) of the manufactured fiber reinforced composite materials (with varied volume fraction).
- Through using Finite Element Method, estimate the effective thermal conductivity of these fiber reinforced polymer composite systems (FEM). To mimic the architecture of composite materials at varied filler concentration 3-D cylinders in cube structures are built.
- Evaluation of the developed framework through comparison of thermal conductivities derived from the developed framework with values acquired from Analytical model and experiments.
- Ultimately, the above-mentioned manufactured composites are recommended for specific purposes.

## 3. MATERIALS AND METHODS

For improved thermal shielding, the different measures and fiber dispersion are determined to be more important than polymer formulation. This section presented the materials and procedures employed in the composites processes under examination. It describes the characterization and thermal conductivity experiments that were performed on the composite samples. This section also discusses the numerical methods for determining thermal properties using the finite element method.

## 4. MATERIALS

***Matrix material***

Bisphenol-A-Diglycidyl-Ether is its popular name, and Figure 3.1 depicts its chemical supply chain. When paired with the hardener tri-ethylene-tetramine (TETA), an aliphatic primary amine with the trade designation HY 951, it offers a solvent-free room temperature drying system (Figure 3.2). Ciba Geigy India Ltd. provides the LY 556 epoxy resin (Figure 3.3) and the associated hardener HY951. Table 3.1 lists some of the key features of epoxy.

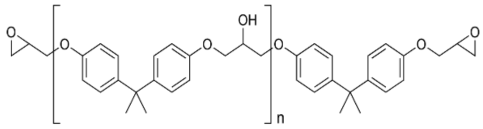


**Figure 2: An unprocessed epoxy resin chain (the number "n" shows the number of polymerized units).**

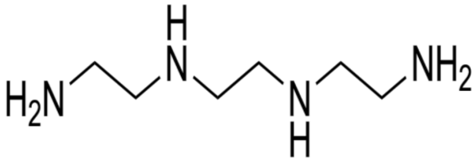


**Figure 3: Triethylene-tetramine (hardener used)**

**Table 1: Several key epoxy qualities**

| Characteristic Property | Inferences |
|---|---|
| Density | 1.1 gm/cc |
| Compressive strength | 90 Mpa |
| Tensile Strength | 58 Mpa |
| Thermal Conductivity | 0.363 W/m-K |
| Glass Transition Temperature | 104°C |
| Coefficient of Thermal expansion | 62.83 ppm/°C |
| Electrical conductivity | $0.105 \times 10^{-16}$ S/cm |

***Filler material - 1 (Glass fiber)***

**Table 2: Some important properties of glass fiber**

| Characteristic Property | Inferences |
|---|---|
| Density | 1.5 gm/cc |
| Compressive strength | 1080 Mpa |
| Tensile strength | 3445 Mpa |
| Thermal Conductivity | 0.18 W/m-K |

**Figure 4: Short glass fiber used as filler in the present work**

***Filler material - 2 (Banana fiber)***

**Table 3: Some important properties of banana fiber**

| Characteristic Property | Inferences |
|---|---|
| Density | 0.2 gm/cc |
| Compressive strength | 22.25 Mpa |
| Tensile strength | 49.85 Mpa |
| Thermal Conductivity | 0.09 W/m-K |

**Figure 5: Short banana fiber used as filler in the present work**

## 5. SCOPE OF THE PRESENT WORK

This study paves the way for prospective researchers to investigate several other features of the thermal characteristics of fiber reinforced polymer composites. Some research strategies for the present work are listed below:

The present study encourages the investigations on varying volume concentrations, various proportions of epoxy/glass fiber and epoxy/banana fiber composites can be productively manufactured using a simple hand lay-up process.
Finding the suitable numerical model (FEM model by means of ANSYS) to correlate with the parameters determined from other means.
To demonstrated that the Finite element technique (FEM) may be effectively used to determine the nominal heat conductivity of different fibers reinforced composites with varying fiber volume concentrations.
To investigate the parameters such as fiber loading, thermal conductivity, fiber volume fraction, thermal behavior of filler/resins etc. for the proposed composites in the present work.
To check the suitability of the prepared/examined composites for the different load load/thermal applications.

## 6. EXPERIMENTAL DATA AND BENCH MARK

***Experimental details***
*Composite fabrication*

Set 1: Epoxy composites bonded with short glass fibers for FEM modelling validation The low temperature curing epoxy resin (LY 556) and curing agent (HY951) are combined in a weight-to-weight ratio of 10:1. Small glass fibers were strengthened in resin to form composites in various quantities based on the requirements. The consistently mixed batter is then gradually poured into glass moulds that have been previously sprayed with wax and a homogeneous thin film of silicone-releasing reagent. The composites were cast in these moulds to produce disc-shaped specimens (diameter 50 mm, thickness 3 mm). Composites of six distinct formulations with varying volume fractions are created. The moulds were left to dry at room temperature for approximately 24 hours before the glass moulds were shattered and specimens were freed. Table 5.1 illustrates the varied compositions of manufactured composites utilizing glass fiber as filler for FEM modelling validation.

**Table 4: Collection of fiber-reinforced polymer composites made by hand-lay-up approach for FEM Simulation & Evaluation**

| Sample | **Composition (Glass fiber as filler material)** | **Composition (Banana fiber as filler material)** |
|---|---|---|
| 1 | Epoxy + 2.83 vol% Glass fiber | Epoxy + 2.83 vol% Banana fiber |
| 2 | Epoxy + 5.65 vol% Glass fiber | Epoxy + 5.65 vol% Banana fiber |
| 3 | Epoxy + 7.54 vol% Glass fiber | Epoxy + 7.54 vol% Banana fiber |
| 4 | Epoxy + 10.05 vol% Glass fiber | Epoxy + 10.05 vol% Banana fiber |
| 5 | Epoxy + 12.56 vol% Glass fiber | Epoxy + 12.56 vol% Banana fiber |
| 6 | Epoxy + 15.70 vol% Glass fiber | Epoxy + 15.70 vol% Banana fiber |

Set 2: Epoxy composites bonded with short glass fibers for numerical method evaluation small glass fibers were strengthened in the resin using the same hand lay-up approach to generate composites of six variable composition with varying volume fractions. The composites were cast on glass moulds to produce disc type examples with identical sizes, as shown in figure 5.2. Table 5.2 illustrates the varied compositions of manufactured composites utilising glass fiber as filler for numerical methods evaluation.

Set 3: Epoxy Composites Reinforced with Short Banana Fibers for Numerical Model Evaluation In a similar way, epoxy reinforced with short banana fibers composites of 6 more various configurations were decided to make, and the composites have been channelled in glass moulds to obtain two very different disc type samples with the same measurements, as shown in figure 5.3. Table 5.2 also shows the varied compositions of manufactured composites with banana fiber as filler for computational mathematics evaluation.

**Table 5: Collection of fiber-reinforced polymeric materials made by hand-lay-up approach for proposed mathematical evaluation**

| Sample | **Composition (Glass fiber as filler material)** | **Composition (Banana fiber as filler material)** |
|---|---|---|
| 1 | Epoxy + 2.83 vol% Glass fiber | Epoxy + 2.83 vol% Banana fiber |
| 2 | Epoxy + 5.65 vol% Glass fiber | Epoxy + 5.65 vol% Banana fiber |
| 3 | Epoxy + 7.54 vol% Glass fiber | Epoxy + 7.54 vol% Banana fiber |
| 4 | Epoxy + 10.05 vol% Glass fiber | Epoxy + 10.05 vol% Banana fiber |
| 5 | Epoxy + 12.56 vol% Glass fiber | Epoxy + 12.56 vol% Banana fiber |
| 6 | Epoxy + 15.70 vol% Glass fiber | Epoxy + 15.70 vol% Banana fiber |

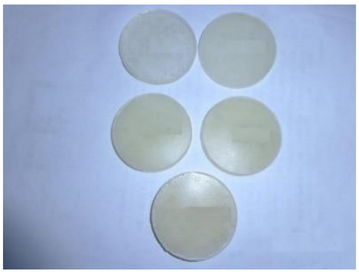


**Figure 6: Short glass fiber reinforced epoxy composites**

**Thermal conductivity characterization**

*Experimental determination of thermal conductivity*
Unitherm Model 2022 Guarded Heat Flow Meter Thermal Conductivity Measurement System from Nortest

The Unitherm Model 2022 measures the thermophysical properties of different materials. Polymers, composites, ceramics, glasses, rubbers, some metals, as well as other substances with low - to - medium thermal resistance are examples of these materials. To determine thermal conductivity, a tiny sample test material is required. Thermal conductivity of nonsolid materials including such glues, pastes, and fluids is measured using various containers. The testing is carried out in compliance with ASTM standards.

E1530 is a standard. For testing at temperatures below atmospheric, a tightly sealed compartment is employed to create a moisture-free atmosphere using dry air purge. The thermal conductivity of polymers is measured through the melt using Superior suppression cells.

*Operating principle of Unitherm-TM 2022*

**Figure 7: Determination of Thermal Conductivity Using Unitherm Model 2022**

A chiller blower is available as an option to fully utilise the device's capability, which may give heat sink temperatures as low as -10°C or as high as -60°C for the cryogenic variant. One of three different frequency modules is included with the Unitherm Model 2022. Every phase contains a different thermal sensitivity area, and each panel is field interchangeable. A consistent compressive force is applied to a sample test material between two temperature-controlled surfaces. The eventually drop of the sample test material is attached to a validated heat flow sensor. For the development of an axially temperature variation in the stacking, the pattern of heat transfer within the specimen is from top surface to bottom surface. The heat transfer of the specimen test sample is calculated using the obtained values and the sample thickness. Thermometers are used to measure the change in temperature in the high conductivity steel substrate layers along either side of the specimen.

We understand that a structure's heat transfer gives the quantity of energy carried through a mass of unit surface area and unit thickness in unit time when the temperature gradient between both the surfaces generating heat flow is unit difference in temperature. Equation 1 represents the Fourier's equation for 1-D conduction of heat.

$$Q = KA\frac{T_1 - T_2}{x} \text{ --------------- } (1)$$

Where,
Q is the heat transfers (W)
K is the thermal conductivity of the material (W/m-K)
A is the cross-sectional area through which heat is transferred (m)
T1-T2 is the temperature difference (K)
X is the thickness of the sample (m).
The thermal resistance of a test sample material can be given as,

$$Q = \frac{T_1 - T_2}{\frac{Q}{A}} \text{ ---------------------- } (2)$$

Where,
R is the resistance of the sample (m2K/W)
From Equations 5.1 and 5.2 we can derive that.

$$K = \frac{x}{R} \text{ ---------------------- } (3)$$

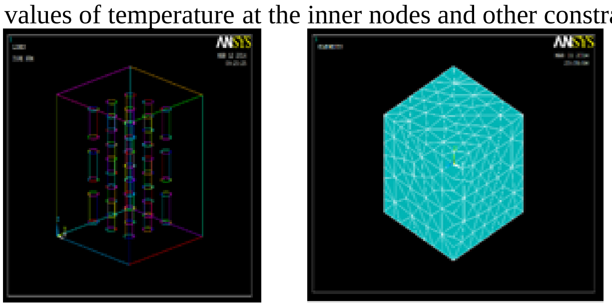
The temperature gradient across the specimen test material between both the top and bottom plates is determined using a heat flow sensor in the Unitherm model 2022. Thus, the material's thermal performance can be computed between both the upper and bottom surfaces. Using the thickness data input and the specified cross-sectional size, the heat transfer of the specimens can be computed.

Section summery

This section has provided:
A description of the finite element approach.
The description of the ANSYS steps.
Specifics about the materials used in the research.
The hand-lay-up methodology used to fabricate the composites.
An explanation of thermal conductivity measurement.
The following section covers the findings of the numerical methods, analytical method, and experiments used to determine the thermal conductivity of the polymer composites under consideration.

## 7. RESULTS AND DISCUSSION

The orientation of thermal expansion within the composite lamina and the initial conditions used to examine this thermal performance issue for the composite system reinforced by short fibers are shown in Figure 8. The temperature at the nodules along the surface ABEF serves as the input to this heat transfer problem. The average temperature ABEF is specified as 100° C. Thermal convection heat transfer takes place between the composite lamina and the lower atmosphere, with the heat transfer coefficient for convection estimated to be 2.5 W/m$^2$ -K at 27°C. All the other faces normal to the surface of heat flow are thought to be adiabatic. ANSYS is used to calculate the unknown values of temperature at the inner nodes and other constraints.



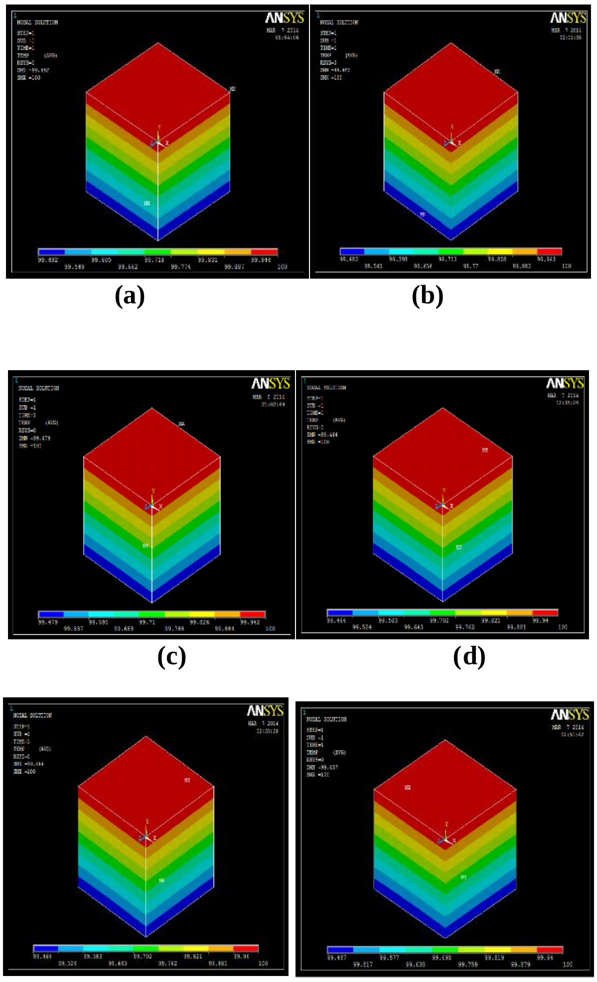
**(a) (b)**

**Figure 8: Short fiber in cube model (3-D) (a) Fiber configuration within matrix body, (b) Prototype meshing**

*Effective thermal conductivity of the composites*

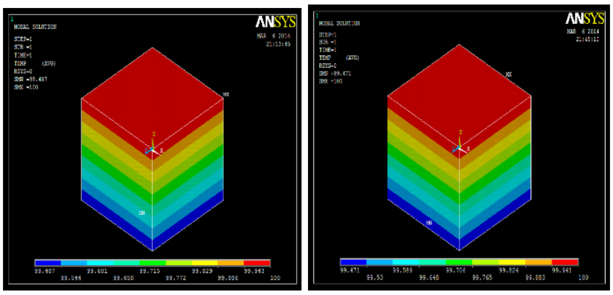
Figure 8 shows the 3-D view of short fiber in cube model. A typical arrangement of short fiber within the matrix body is shown in Figure 8(a) where fibers are uniformly distributed within the resin and heat is transferred from top to bottom along the axial direction of the fiber.

Figure. 8(b) shows the meshed view of such fiber in cube model where size of the meshing element purely depends upon the dimension of short fiber. By applying the various boundary conditions, the temperature profiles can be obtained which are presented in Figure 9 and Figure 10. Figure 9 (a-f) shows the temperature profiles for glass fiber reinforced epoxy composites with fiber volume fraction of 2.83, 5.65, 7.54, 10.05, 12.56 and15.7 vol% respectively.

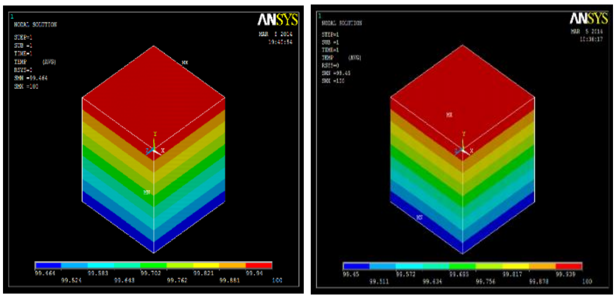


(a) (b) (c) (d) (e) (f)

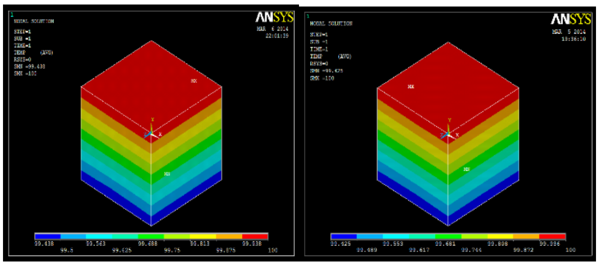
**Figure 9: Temperature distribution of composites with glass fiber loading (a) 2.83 percent by volume (b) 5.65 percent by volume (c) 7.54 volume percent (d) 10.05 volume percent (e) 12.56 volume percent (f) 15.7 volume percent**



(a) (b)



**(c)** **(d)**



**(e)** **(f)**

**Figure 10: Temperature profile of composites with (a) 2.83 vol percent banana fiber loading and (b) 5.65 vol percent banana fiber loading (c) 7.54 volume percent (d) 10.05 volume percent (e) 12.56 volume percent (f) 15.7 volume percent**

Figure 10 depicts the temperature curves for banana fiber reinforced epoxy composites (a-f). Measurement of $K_{eff}$ values for several sets of epoxy-fiber composites are computed using varied temperature profiles. Table 6 displays the $K_{eff}$ values for various approaches as well as the experimental data for glass fiber reinforced epoxy composites. Table 7 shows similar values for banana fiber reinforced epoxy composites.

**Table 6 shows the $K_{eff}$ measurements for glass fiber reinforced composite material achieved using multiple techniques.**

| Sample | Fiber Loading (vol%) | Effective thermal conductivity of the composite (W/mK) | | | | | |
|---|---|---|---|---|---|---|---|
| | | ROM | Maxewell model | Lewis-Nilsen model | Proposed model | Experimental Values | FEM |
| 1 | 2.830 | 0.353 | 0.356 | 0.357 | 0.357 | 0.360 | 0.357 |
| 2 | 5.650 | 0.343 | 0.350 | 0.345 | 0.352 | 0.356 | 0.350 |
| 3 | 7.540 | 0.337 | 0.346 | 0.339 | 0.349 | 0.352 | 0.347 |
| 4 | 10.050 | 0.328 | 0.340 | 0.329 | 0.343 | 0.346 | 0.342 |
| 5 | 12.560 | 0.322 | 0.336 | 0.323 | 0.339 | 0.341 | 0.338 |
| 6 | 15.700 | 0.313 | 0.329 | 0.313 | 0.334 | 0.337 | 0.333 |

**Table 7 shows the $K_{eff}$ measurements for banana fiber reinforced composite material achieved using various approaches.**

| Sample | Fiber Loading (vol%) | Effective thermal conductivity of the composite (W/mK) | | | | | |
|---|---|---|---|---|---|---|---|
| | | ROM | Maxewell model | Lewis-Nilsen model | Proposed model | Experimental Values | FEM |
| 1 | 2.83 | 0.344 | 0.353 | 0.354 | 0.355 | 0.359 | 0.353 |
| 2 | 5.65 | 0.309 | 0.343 | 0.345 | 0.347 | 0.352 | 0.342 |
| 3 | 7.54 | 0.295 | 0.336 | 0.339 | 0.342 | 0.348 | 0.338 |
| 4 | 10.05 | 0.275 | 0.326 | 0.329 | 0.334 | 0.342 | 0.329 |
| 5 | 12.56 | 0.263 | 0.319 | 0.323 | 0.328 | 0.336 | 0.322 |
| 6 | 15.7 | 0.246 | 0.308 | 0.313 | 0.319 | 0.329 | 0.315 |

Figure 11 depicts a correlation of the heat transfer coefficients of glass fiber reinforced composite material gathered from multiple existing models such as the Rule of Mixture, as well as the suggested model, FEM analysis, and experimental data.

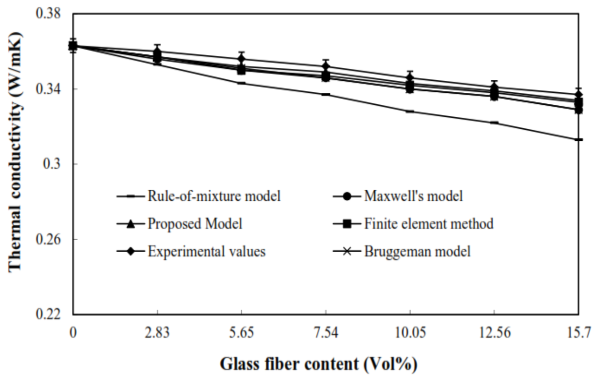



**Figure 11: Thermal conductivity of short glass fiber/epoxy composites: Maxwell's model, Bruggeman model, proposed model, FEM, and experimental values**

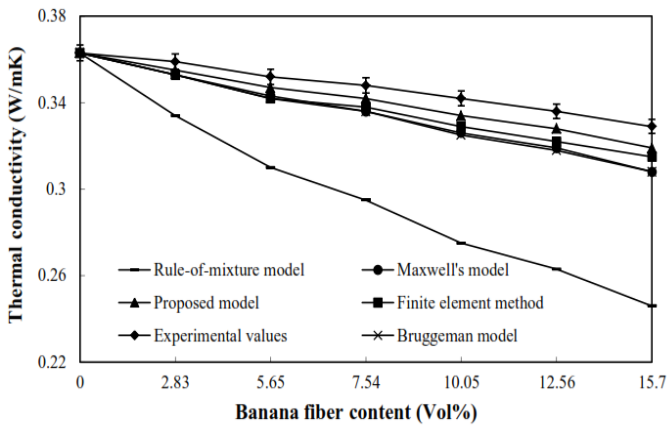



**Figure 12: Thermal conductivity of short banana fiber/epoxy composites: Maxwell's model, Bruggeman model, proposed model, FEM, and experimental values**

Figure 12 depicts a comparable comparison for banana fiber reinforced composite material. Both figures show that even as the fiber loading in the epoxy resin grows, the values of $K_{eff}$ fall, which is understandable given that both fibers have low inherent thermal conductivity when compared to epoxy resin. All calculations, mathematical simulations, and observed data continue the pattern.

**Table 8: Percentage variations in relation to the measured result for glass fiber/epoxy composites**

| Sample | Fiber Loading (vol%) | Effective thermal conductivity of the composite (W/mK) | | | | |
|---|---|---|---|---|---|---|
| | | ROM | Maxewell model | Lewis-Nilsen model | Proposed model | FEM |
| 1 | 2.83 | 1.983 | 1.123 | 0.841 | 0.843 | 0.84 |
| 2 | 5.65 | 3.79 | 1.714 | 1.424 | 1.424 | 1.714 |
| 3 | 7.54 | 4.451 | 1.734 | 1.149 | 1.734 | 1.44 |
| 4 | 10.05 | 5.487 | 1.764 | 1.169 | 1.765 | 1.169 |
| 5 | 12.56 | 5.901 | 1.488 | 1.186 | 1.488 | 0.887 |
| 6 | 15.7 | 7.667 | 2.431 | 1.813 | 2.431 | 1.201 |

According to the tables, the variations related with reverence to the calculated observations for glass fiber reinforced epoxy composite for developed framework, FEM values, are in the range of 0.8-2 percent, and for rule-of-mixture model they are in the range of 2-8 percent.

**Table 9: Percentage variations in relation to the experimental results for banana fiber/epoxy Composites**

| Sample | Fiber Loading (vol%) | Effective thermal conductivity of the composite (W/mK) | | | | |
|---|---|---|---|---|---|---|
| | | ROM | Maxewell model | Lewis-Nilsen model | Proposed model | FEM |
| 1 | 2.83 | 7.485 | 1.608 | 1.699 | 1.127 | 1.169 |
| 2 | 5.65 | 13.548 | 2.624 | 2.924 | 1.441 | 2.924 |
| 3 | 7.54 | 17.966 | 3.571 | 3.571 | 1.754 | 2.958 |
| 4 | 10.05 | 24.363 | 4.908 | 5.231 | 2.395 | 3.951 |
| 5 | 12.56 | 27.756 | 5.329 | 5.66 | 2.439 | 4.347 |
| 6 | 15.7 | 33.739 | 6.818 | 6.818 | 3.135 | 4.444 |

Fig. 15 shows a comparable evaluation of the measured value of banana fiber and glass fiber reinforced composite material for experimentation.

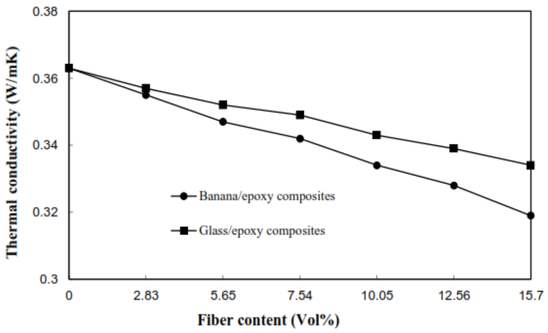



**Figure 13: Correlation of the $K_{eff}$ measurements for both the reinforcements (Proposed model)**

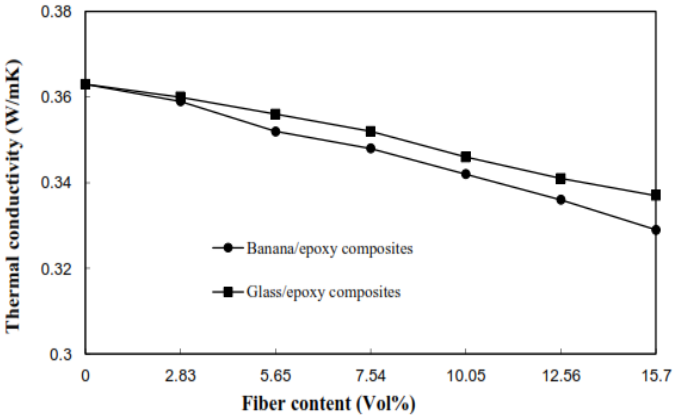



**Figure 14: Correlation of the $K_{eff}$ measurements for both the filler (FEM model)**

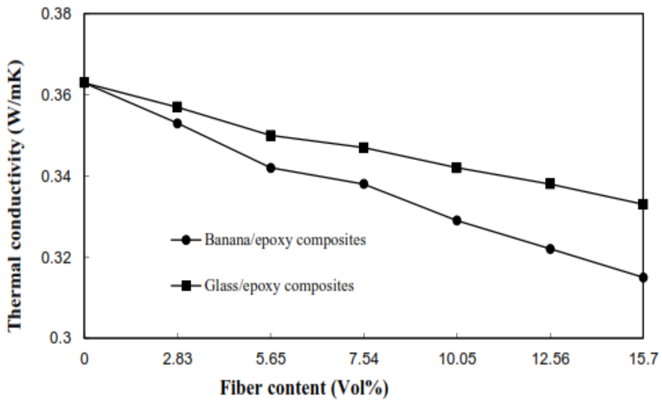



**Figure 15: Correlation of the $K_{eff}$ measurements for both the filler (experimental model)**

The contrast chart illustrates that the drop in measurements for banana fiber reinforced polymer composites is greater than that for glass fiber reinforced epoxy composites, which is understandable given that banana fiber has reduced thermal resistance than glass fiber. Banana fibers also feature non-corrosive, recyclable, less-expensive, renewable qualities. As a result, a natural fiber, such as banana fiber, can be utilized to substitute a renowned artificial fiber, such as glass fiber, for isolation and reinforcing in composite materials.

**Section summery**

This section presents the findings of the quantitative simulation, analytical method, and measurements used to assess the thermal comfort of the polymeric materials under consideration. For various volume percentages of fibers, measurable estimates of heat transfer coefficients are determined. The incorporation of fiber reduces the heat conductivity of the epoxy resin, improving its insulation material capabilities. A decrease in $K_{eff}$ of 8% is observed for composites with 15.7 vol percent glass fiber addition, however for banana fiber it is reduced to 12% for identical fiber loading. The following section contains the findings from the study given in this thesis, as well as suggestions for future work.

## 8. CONCLUSIONS AND SCOPE OF THE FUTURE WORK

***Conclusions***

Based on the statistical, theoretical, and practical research of the thermal properties of fiber-reinforced composites (glass fiber and banana fiber), it is possible to conclude:

For varying volume concentrations, various proportions of epoxy/glass fiber and epoxy/banana fiber composites can be productively manufactured using a simple hand lay-up process.

The standards produced from the suggested statistical representative are very close to the calculated data for all of the prepared composites across the whole variety of fiber content.

The proposed analytical model's findings are also more accurate than the parameters determined from FEM model by means of ANSYS.

It is demonstrated that the Finite element technique (FEM) may be effectively used to determine the nominal heat conductivity of different fibers reinforced composites with varying fiber volume concentrations.

The investigation demonstrates that when the fiber loading in the composite increases, the $K_{eff}$ decreases dramatically. With the inclusion of 15.7 vol percent of glass fiber in epoxy resin, the value of the $K_{eff}$ is reduced by around 8%, even though a 12 percent fall is observed when the fillers is banana fiber.

It may also be observed that banana fiber - reinforced composites epoxy composites have markedly decreased key parameters than glass fiber reinforced epoxy composites. Banana fibers also feature non-corrosive, recyclable, low-cost, reusable qualities. As a result, a natural fiber, such as banana fiber, can be utilized to substitute a very well synthetic fiber, such as glass fiber, for insulation and reinforcing in composite materials.

Because of their light mass and low thermal properties, these fiber-reinforced polymer composites have prospective uses in insulating boards, kitchen utensils, thermo flasks, construction materials, and so on.

***Scope for future work***

This study paves the way for prospective researchers to investigate several other features of the thermal characteristics of fiber reinforced polymer composites. Some research strategies for the future include:

Investigating the influence of filler orientation and size on composite thermos-physical properties.

Research into novel reinforcement materials and polymers for the manufacture of different materials with reduced thermal and electrical conductivity.

Various polymeric resins and plant materials may be used in the implementation of novel composite samples.

Research into how these composites react to different wear patterns like as abrasion and slurry erosion.

Research the influence of reinforcement material forms and size on composite thermal characteristics.

## 9. REFERENCES


[1] Gad Marom, Albert Reuveni and Daniel Cohn, "Stiffness Variabilit y and Stress Dependent Elastic Response of Synthetic Fiber-Reinforced Composites for Biomedical Applications", Biomaterials, Vol. 14, No. 2, 1993.

[2] Vijay Kumar Thakur and Manju Kumari Thakur, "Processing and Characterization of Natural Cellulose Fibers/Thermoset Polymer Composites", Carbohydrate Polymers, Vol.109,pp. 102–117, 2014.

[3] Yongli Zhang, Yan Li, Hao Ma and Tao Yu, "Tensile and Interfacial Properties of Unidirectional Flax/Glass Fiber Reinforced Hybrid Composites", Composites Science and Technology, Vol. 88, pp. 172–177, 2013.

[4] Cho, J., Chen, J. Y. & Daniel, I. M. "Mechanical Enhancement of Carbon Fiber/Epoxy Composites by Graphite Nanoplatelet Reinforcement", Scripta materialia, Vol. 56 (8), pp. 685 688, 2007.

[5] Chauhan, S. R., Gaur, B. & Dass, K. "Effect of Fiber Loading on Mechanical Properties, Friction and Wear Behaviour of Vinylester Composites Under Dry and Water Lubricated Condit ions", International Journal of Material Science,Vol. 1(1), pp. 1-8, 2011.

[6] Huang, G. & Sun, H. "Effect of Water Absorption on the Mechanical Properties of Glass/Polyester Composites", Materials & design, Vol.28, pp.1647-1650. 2007.

[7] Stephen Tsai and Thomas Hann, "Introduction to Composite Materials", Technomic Publications, Lancaster, 1980

[8] Zhong-Hong Jiang and Qin-Yuan Zhang, "The Structure of Glass: A Phase Equilibrium Diagram, Approach", Progress in Materials Science, Vol. 61, pp. 144–215, 2014.

[9] Alexander Markov, Bodo Fiedler and Karl Schulte, "Electrical Conduct ivit y of Carbon Black/Fibers Filled Glass-Fiber-Reinforced Thermoplast ic Composites", Composites: Part A, Vol. 37, pp. 1390–1395, 2006.

[10] D. Olmos and J. Gonzalez-Benito, "Visualization of the Morphology at the Interphase of Glass Fiber Reinforced Epoxy-Thermoplast ic Polymer Composites", European Polymer Journal, Vol. 43, pp. 1487–1500, 2007.
[11] A. Bergeret, L. Ferry and P. Ienny, "Influence of The Fiber/Matrix Interface on Ageing Mechanisms of Glass Fiber Reinforced Thermoplastic Composites (PA-6, 6, PET, PBT) In A Hygrothermal Environment", Polymer Degradation and Stabilit y, Vol. 94, pp. 1315–1324, 2009.
[12] S. Barre, T. Chotard and M. L. Benzeggagh, "Comparat ive Study of Strain Rate Effects on Mechanical Properties of Glass Fiber- Reinforced Thermoset Matrix Composites" Composites Part A, Vol. 27A, pp. 1169-1181, 1996.