EXPERIMENTAL INVESTIGATION OF THERMAL PROPERTIES OF KENAF COMPOSITE

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EXPERIMENTAL INVESTIGATION OF THERMAL PERFORMANCE OF KENAF COMPOSITE

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in fulfillment of the requirement for the degree of
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SUPERVISOR'S DECLARATION

I declare that this project report entitled "Experimental Investigation Of Thermal Performance Of Kenaf Composite" is the result of my own work except as cited in the references.

Signature : ....

Name : ....

Date : ....

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Thermal-Fluids).

Signature :. ....

Name of Supervisor : ....

Date : ....

DEDICATION

My mother and father is the one who brings out the best of me.

To my beloved friends and all my lectures, thank you.

ABSTRACT

A composition material, also called as composite material is a material that is made from a combination of two or more materials at different physical characteristic, to produce a material at the new traits. Kenaf composite has been study in this research. The thermal conductivity of the kenaf composite was studied depth with the various composition of kenaf fibre and the polypropylene is act as the resin. It was found that the thermal conductivity of the kenaf composite decrease as the kenaf fibre composition increase in the composite. The infrared lamp was used to supply heat constantly to the composite. By using the equation of thermal conductivity, the thermal conductivity was calculated and the data is tabulated in this study.

ABSTRAK

Bahan komposisi, juga dikenali sebagai bahan komposit adalah bahan yang diperbuat daripada gabungan dua atau lebih bahan-bahan pada ciri-ciri fizikal yang berbeza, untuk menghasilkan bahan yang pada ciri-ciri baru. Kenaf komposit telah kajian dalam kajian ini. Kekonduksian terma komposit kenaf telah dikaji mendalam dengan komposisi pelbagai serat kenaf dan polipropilena adalah bertindak sebagai resin. Ia telah mendapati bahawa kekonduksian terma penurunan komposit kenaf peningkatan serat komposisi kenaf dalam rencam. Lampu inframerah digunakan untuk membekalkan haba sentiasa untuk rencam. Dengan menggunakan persamaan kekonduksian haba, kekonduksian haba telah dikira dan data yang dibentangkan dalam kajian ini.

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LIST OF ABBEREVATIONS

PP	Polypropylene

LIST OF SYMBOL

k	=	Thermal conductivity
m	=	Mass
Q	=	Heat flow (Power supply)
A	=	Area
ρ	=	Density
T	=	Temperature
ΔT	=	Temperature difference
L	=	Thickness
t	=	Time

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Composite is known as combine materials between a natural composite, consisting of one species of a polymer which is cellulose fibers with resin like polypropylene. A composite can improve utilization of their excellencies and minimizing some degree that effects of their deficiencies. The example of fibers that used in the composite are carbon, glass and sometimes the presence of wood or natural fibers. The polymer that are usually epoxy, phenol formaldehyde, vinylester or polyester thermosetting plastic resins. Most of composites are strong because of the rigid fibers in a matrix form. Manufactured strands (synthetic fiber) like glass fiber, nylon, carbon fiber and so forth are thought to be potential filler material for different applications like wear safe and basic parts. Glass fiber strengthened polymer framework composites are imperative building materials, basically on account of their low thickness in mix with amazing particular firmness and quality. This engineered fiber is observed to be potential filler for enhancing protection ability of different polymers on account of its low warm conductivity. Be that as it may, these manufactured fibers strengthened polymer composite have a few impediments like they are destructive and dangerous in nature, higher cost and non-biodegradable.

Kenaf, *Hibiscus Cannabinus L.* is a one of the faster crops to yield per year and can be used as the natural composite. Component parts in kenaf are bast fiber, leaves. Each of the component is used in the industry nowadays. The core of kenaf can be used as soil amendments, oil absorbents in chemical industry and as animal beddings. The fiber is the source in the cottage industry too trough out the world (Agbaje et al. 2008). The components of this plant contained two different type of fibers. The first one is; it has a long fiber strands which are composed by individual of smaller bast fibers. the second one is the whole trunk kenaf, that were used to produce paper, ropes, twine, burlap fiberboard and coarse (Hossain et al. 2011)**.** There are different in tensile strength between the core fiber and the bast fiber. Kenaf bast fibers have higher tensile strength between the kenaf core fiber. it was proved by Ishak et al. (2010) in his study where the tensile strength of bast fibers 20Mpa, which is higher than core fibers that is 16MPa. Kenaf is a mechanical yield with high potential for development in a tropical atmosphere. Various innovations and skill among scientists have been created to upgrade kenaf generation in Malaysia. Oil palm, rice, rubber, coconut and mixed horticulture are the major crops planted in Malaysia. As the third largest exporter of lumber industry in the world, there was about 76.3% of forest that covered the land in Malaysia and the percentage decrease gradually to 62% in 2009 due to high demand for lumber, causing the rate of deforestation increased (Hadi et al. 2014).

1.2 PROBLEM STATEMENT

Malaysia is known as equator climate and has average 2500 millimetre (calculated from November to February). This climate results in the room temperatures, especially in the office, building and houses to increase. The air conditioning and the air ventilation system are used to cool down the room or building temperature in some building such as government office or classroom. However, there is also another because that effect the temperature alone, which is the ceiling tiles that was applied in the room. Noticed that the ceiling in the major office is a fiberglass type ceiling and has low thermal conductivity. This allowing the heat to be transferred easily into the building and reheat the room temperature.

1.3 OBJECTIVE

The objective of the project as this follow:

a) To study the thermal properties of different ratio of fibers/polypropylene.
b) To obtain thermal properties of kenaf composite.
c) To provide a complete analysis of thermal conductivity of kenaf composite

1.4 SCOPE OF PROJECT

The scope of this project are:

a) Only results of analysis and thermal performance of kenaf composite are presented in this report.
b) Determination of thermal conductivity by experimental method.
c) Fabrication of kenaf composite involved the hot-pressing technique.
d) Carry out the thermal properties analysis.

1.5 GENERAL METHODOLOGY

The actions that is need to be carried out to achieve the objectives in this project are listed below.

1) Literature review

   Journals, articles, books, or any other resources regarding the project will be reviewed.

2) Inspection

   The ceiling of the office in the building will be inspected and identify the material used to for the ceiling.

3) Preparation

   Preparing apparatus and materials that is needed to conduct the experiment.

4) Analysis

   Analysis will be presented about the thermal conductivity of the kenaf composite and the result will be discussing and compared with the ceiling based on the analysis.

5) Report writing.

   A report on this study will be written at the end of the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction of Kenaf

Kenaf (*Hibiscus cannabinus L.*) is a warm season woody-herbaceous plant from *Malvaceae* family. It is an important short-day annual plant with fast growing and straight, single and branchless stem. It will produce branches if grown under wider arrangement. Kenaf has a resemblance with okra (*Hibiscus esculentus*), cotton (*Gosypium hirsutum L.*), hollyhock (*Althaea rosea*), and hibiscus (*Hibiscus hibiscum L.*) (Charles et al. 2002).

Table 2.1-a: Scientific information of kenaf (Source: Author)

Kingdom	Plantae (Planta, plants)
Division	Magnoliophyta (angiosperms, flowering plants, angiospermes)
Class	Magnoliopsida (dicots, dicotyledons)
Other	Malvales
Family	Malcaveae (mallows)
Genus	Hibiscus (hibuscus, rose mallow)
Species	cannabinus (brown Indian hemp)

The origin of kenaf was reported from Africa (North Africa, east Africa) and has been grown for food and fiber to produce rope, twine, and sackcloth. Kenaf is grown anually but it can become perpetual under a certain environments. It has a high potential in terms of lignocellulosic material or fiber and a fast growing plant. In a three months, the growth of kenaf can achieve to three meters even it was plant in moderate ambiet conditions, with a stem diameter of 25mm to 51mm. It is also can growth to five – six meters if plant under good conditions in six to eight months. Most of kenaf colors are in green but it was reported there are several purple and red stemmed accessions (Aji et al. 2009).

The stem consists of three layers which phloem (an outer cortical tissue layer-bark), xylem (an inner woody tissue layer-core), and a thin central pith layer that has sponge-like tissue with mostly non-ferrous cells and it is a dicotyledonous plant. The bark and core can be differentiate by their chemical composition, structural characteristics and chemo-physical properties. For example, the core lignin is different from the bark lignin in content and chemical structure, the core is the main tissue of the stem and has larger cross-sectional area compared with the bark. The core or inner fiber together with the pith covers 60% of the stem's dry weight while the bark portion covers around 40% of the stem's dry weight.

Fibers from the core are about 0.6mm long and resemble hardwood fibers while from the bark portion of the stem are about 2.5 m long. The bark have higher compositions in α-cellulose, ash content and extractive while the core are higher in holo-cellulose and lignin (Abdul Khalil et al. 2010). There is difference in the quality of core and bark fibers. The core that rich in lignin produce a pulp with poor strength properties as the cross-linking characteristics of the lignin macromolecule and three-dimensional structure causing in poor initial fiber bonding and collapse (Mossello et al. 2010).

Kenaf plant has a relatively deep, wide-raging lateral root system and a long effective taproot system, making the plant drought tolerant (Nasreen et al. 2014). The kenaf's leaf can be mistaken for the illegal weed because it looks like marijuana (Cannabis sativa) and looks like cotton and okra (Stricker et al. 2006). Kenaf plant maturity influencing the composition and quality of plant components, as well as total biomass harvested. As the age and height of kenaf plant increase, the crude protein percent and leaf biomass percentage decreased. Kenaf cultivars influenced by the growing season, adequate soil moisture, and the average day and night temperatures (Webber & Bledsoe 2002).

Kenaf yields been highest in area with abundant soil moisture, high temperature and a long term growing season. The kenaf plant is held to have larger range of adaptation to soils and climates than any other fiber plant in viable production. As stated by LeMahieu et al. (n.d.), diversity development for acceptance to soil temperature and cool air can expand kenaf's region of productive adaptation. Kenaf cultivation recommended to have higher than 12.5 hours of daytime to avoid reduction in growth related with flowering and fruit development. Kenaf is suitable grown in 45°N to 30°N that are located a warm temperature zone to the equator with a maximum elevation of around 500 meter (El Bassam, 2010).

According to Blackburn (2005), although kenaf can grow effectively in a varied range of soils, from sandy desert soils to high organic turf soils, it grows best on fertile soils at neutral pH, well-drained. It can withstand at low soil fertility and flooding season. However, it does not do well in prolonged stages of standing water and severe drainage problems (LeMahieu et al., n.d.).

2.1.1 History of kenaf

Kenaf was introduced to China in 1935 by Russia as Russia has started producing it in 1902. During World War II, kenaf production and research has begun in the United States as it purposes to supply cordage material for the war. Kenaf was an excellent basis of cellulose fibers for a huge range of paper goods such as bond paper, newsprint and corrugated liner board (LeMahieu et al. n.d.). As stated by Abdul Khalil et al. (2010), the interest in kenaf has increased for its potential use as a commercial fiber crop due to the good fiber quality and fast growth for the manufacture of paper goods and other pulp.

Even though kenaf initiated from Africa, its production is very low. As stated in table 2.1-b, in 2007/08, the production of kenaf by Africa was only $11.2e10^3$ tonnes, which is 4,19% of the total global production. More than 20 countries have commercially cultivated kenaf production and mainly in India and China (International Jute Study Group 2012).

Table 2.1-b: Global word production of kenaf (International Jute Study Group 2012)

Country	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13
China	86.8	84.3	75.2	75.2	78.0	78.0
India	139.7	120.0	131.2	140.0	140.0	120.0
Indonesia	4.7	4.1	3.8	4.0	4.0	4.0
Thailand	2.2	2.9	2.0	1.7	1.7	1.3
Vietnam	25.7	7.8	12.1	5.0	3.2	6.0
Cambodia	0.3	0.3	0.5	0.3	0.4	0.4
Africa	11.2	11.2	10.3	11.8	13.4	13.4

2.1.2 Kenaf plant in Malaysia

In Malaysia, the National Kenaf Research and Development Program has been formed as they realise there are the potentials of commercially practical resulting products from kenaf. It purposed to develop and introduce kenaf as the new industrial crop in Malaysia. Under 9th Malaysia Plan (2006-2010), the government has decided to allocated RM12 million for research and development of kenaf industry. Malaysian Agricultural Research and Development Institute (MARDI) started to plant kenaf in Malaysia. A lot of kenaf plant has planted in Terengganu and Kelantan by Tobacco Board of Malaysia (LTN). Kenaf grows quickly as it can reach to height of 3.66m-4.27m as Malaysia has 12 hours of daylight time which is almost good requirement to grow kenaf.

2.1.3 Advantages of natural fiber including kenaf

Kenaf, one of the natural fibers have some benefits for strengthening materials compared with glass fiber in terms of density, renewability, recyclability, cost, biodegradability and abrasiveness. This results kenaf have good mechanical properties and environmentally harmless. The ability to transfer stress from matrix to the fiber and fiber matrix interface determine the efficiency of the fiber-reinforced composites. In automotive parts, natural composites such as kenaf and polypropylene (PP) have been applied (Shibata et al. 2010).

2.2 Composite

2.2.1 Study on natural fiber composite

A study of shock wave impact of flax fiber reinforced polymer composites on different orientations of fiber was conducted showing that cross polymer fiber orientation has better impact strength than unidirectional fiber orientation. The specimen was prepared by vacuum assisted resin infusion technique and compression molding process method (Huang et al., 2016). Another researcher has study on degradation behaviour of natural fiber reinforced polymer matrix composite that mixed with 5% of wood sawdust and wheat flour for 15 weeks. The composites were exposed in the moist soil, water, atmosphere and brine solution resulted that biodegradability of pure polypropylene has increased due to present of microorganisms and chloride ion in brine solution at atmosphere condition. The wheat polypropylene showing that it has higher biodegradability than wood sawdust due to the ability of wheat to absorb water (Fakhrul & Islam 2013). Ramachandran et al. (2016) have study on various mechanical behaviour on bamboo using linen and banana fiber reinforced polymer composite presented that bamboo epoxy resin composite has lowest result on IZOD and CHARPY test, and bamboo-banana epoxy resin composite score the highest.

2.2.2 Study on thermal conductivity of fiber reinforced polymer composites

Schuster et al. (2008) studied the effect of three-dimensional fiber reinforcement on the out-of-surface thermal conductivity of composites materials. It shows that thermal conductivity increased as the fiber volume fraction increased.

Previous research studied preparing the glass fiber reinforced polymetalphosphate matrix composites by a simple process showed outstanding mechanical properties and thermal insulating. The composites thermal conductivity of 1.12 to 3.45 W/m.K and have maximum flexural strengths at 155Mpa, by hot-press cured composites while the porous auto-clave cured composites has 0.4 to 0.6W/m.K of thermal conductivity and 60 to 70Mpa of maximum flexural strengths (Kim et al. 2003).

2.3 Heat transfer

Temperature difference resulted in the thermal energy that transported from one system to another. On a microscopic level, thermal energy is associated with the vibrations of molecules and the atoms, in kinetic energy. The thermal energy is pass between a system always from a higher temperature gradient to the lower one, and the heat transfer stop as both side achieve the thermal equilibrium. Conduction, convection and radiation are the basic modes of thermal energy transport (Çengel and Ghajar, 2015).

2.3.1 Thermal conductivity

Thermal conductivity, k is a measure of materials to conduct heat flow. Thermal conductivity can be defined as the rate of heat transfer through the unit thickness of the material per unit are per unit temperature difference. Low thermal conductivity of material gives a poor heat conductor properties while high thermal conductivity of materials indicates that a good heat conductor. Normally, the thermal conductivity of gas phase is lower compared with a material in solid phase (Çengel and Ghajar, 2015).

2.3.2 Thermal diffusivity

Thermal diffusivity can be defined as in Eq. (2.1). thermal diffusivity determines how rate of heat diffusion into the material, the ratio of heat conducted through the material to the heat stored in the material per unit volume. When the thermal conductivity is increase, the thermal diffusivity also increase (Çengel and Ghajar, 2015).

$$\alpha = \frac{Heat\ conduction}{Heat\ storage} \tag{2.1}$$

2.3.3 Conduction

The more prominent the temperature contrast, the quicker the heat streams to the colder range. In nineteenth century, a researcher named Joseph Fourier has developed a mathematical theory of heat conduction. The theory was based on the experiment similarly illustrated in Figure 2.1. The solid is insulated on the four side, as it purposed to let the heat across in a one direction only when the heat is applied on the one side, T_1 to opposite side of the solid, T_2. According to the 2nd thermodynamic law, the heat (thermal energy), q will transfer from the hot area to the cold area. It crossing the cross-sectional area, A. The Fourier's law given by Eq. (2.2). The heat conduction can be calculated by using Eq. (2.3).

$$q_x = \frac{kA(T_1 - T_2)}{B} \tag{2.2}$$

$$q = -k\frac{dT}{dx} \tag{2.3}$$

Equation (2.3) is the form of one-dimensional of Fourier's law. From the Eq. (2.3), the heat transfer, q is depending on the temperature gradient and the thermal conductivity, k. Different materials have different thermal conductivities, as shown in Table 2.3-a. The thermal conductivity in Eq. (2.3) is assumed to be constant (Serth & Lestina 2014).

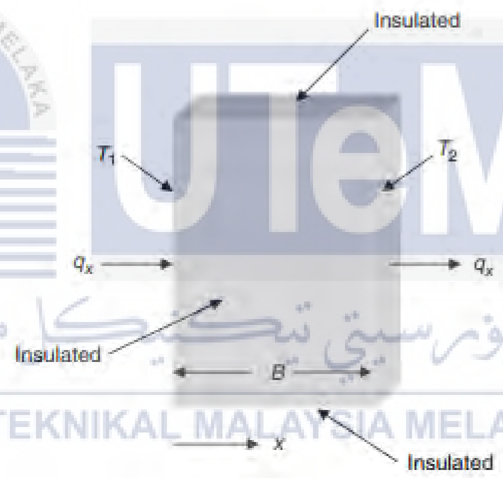

Figure 2.3-a: One dimensional heat conduction in a solit (Serth & Lestina 2014).

Different mediums have different methods of thermal transport. In solids, the heat is transport by using phonon transport and electron transport. The transmission of heat depending on the available energy states as the electron or phonon (heat carrier) scattered as it arrived at the interface sides. The electrons are dominant in metal while phonons are the dominant heat carriers in dielectric material, for example the insulator (Cahill 2012).

Table 2.3-a: Insulation materials thermal conductivities (Çengel and Ghajar, 2015).

Insulation materials	Thermal conductivity, k (W/m.K)
Mineral Fiber	-
Cellular glass	0.055
Expended polystyrene (molded beads)	0.040
Expended perlite (organic bonded)	0.052
Mineral fiber with resin binder	0.042
Polyurethene foam	0.023-0.026
Silica powder	0.0017
Silica aerogel	0.025
Sawdust	0.065
Cork	0.039
Expended rubber (rigid)	0.032
Expanded polyurethene (R-11 expanded)	0.023
Glass fiber (organic bonded)	0.036

2.3.4 Thermal resistance

The heat move through a building development relies on upon the conductivity of the materials utilized, the thickness of the materials, and the temperature distinction crosswise over it. Obviously, the temperature contrast is an outer element. A more higher thickness indicates less heat flow thus does a lower conductivity. Together these parameters shape the heat resistance of the development. The heat resistance is corresponding to the thickness of a layer of the development and contrarily relative to its conductivity. A development layer with a high thermal resistance is a good insulator; one with a low thermal resistance (e.g. cement) is a bad insulator. The thermal resistance of the wall can be calculated as in Eq. (2.4).

$$R_{wall} = \frac{L}{kA} \tag{2.4}$$

Where L is thickness, k is thermal conductivity of material, and A is surface area of the material.

2.3.5 Specific heat

Specific heat is defined as the energy required to raise the temperature of a unit mass of a substance by one degree. The unit of specific heat is kJ/kg.K or kJ/kg.°C (Çengel and Ghajar, 2015).

2.4 Thermal Conductivity Model

In this section, the important models that have been introduced by previous researches will be presented. There are numerous model that has been introduced to determine the thermal conductivity with a known volume fractions and the properties of composite used.

2.4.1 Maxwell model

The first analytical expressions for effective conductivity of composites was proposed by Maxwell with his famous work on magnetism and electricity. Pietrak & Winiewski (2015) state that Maxwell assumes the effective thermal transport in mixture are essentially diffusive. The thermal contacts between filler elements were ignored. However, Maxwell's formula was valid for the case of low volume fraction which is about under 25% of volume fraction.

2.4.2 Rayleigh model

Pietrak & Winiewski (2015) state that Rayleigh take a consideration of thermal contacts between particles. Rayleigh's model illustrated the arrangement of the particles in a continuous matrix. Rayleigh's results have nearly same with Maxwell's results but Rayleigh's model expect to be a better result for greater filler fractions rather than Maxwell's expression.

2.4.3 Hasselman and Johnson model

Pietrak & Winiewski (2015) stated that Hasselman and Johnson states the filler volume fraction and the particle size influence the thermal conductivity of the composite model. Hasselman and Johnson studied the effect of interfacial gaps between matrix and the filler on the thermal diffusivity and conductivity of Ni-glass composites. In formulae by Hasselman-Johnson, the new thing is the necessity of the effective thermal conductivity on the particle radius and the boundary conductivity which is the mutual of interfacial thermal resistance.

2.4.4 Bruggeman model

Pietrak & Winiewski (2015) state that Bruggeman proposed a mathematical formula approach named the differential effective medium scheme (DEM) or differential effective medium theory where the estimation take measure the sum of properties of heterogeneous materials like thermal and electrical conductivities, magnetic permeability or electric permittivity, and thermal diffusivity.

2.4.5 The Lewis-Nielsen model

Pietrak & Winiewski (2015) state that the Lewis-Nielsen equation do not take the measure of interfacial thermal resistance. The mathematical equation shows good results as it was created for below 60% filler volume fractions.

2.4.6 Percolation model

Pietrak & Winiewski (2015) state Devpura et al. (2001) study the size effects on the thermal conductivity of polymers laden with highly conductive filler particles by their percolation model. The percolation model was assumed to be cubic block and it set the conductivity of the matrix is lower than the conductivity of the filler. The prediction by Devpura et al. (2001) has shown a good result with the experimental results.

2.5 Matrix

Polypropylene (PP) is made by polymerizing propylene molecules. It is a thermoplastic polymer. The melting point of PP is ranging from 160°C to 166°C and it depends on the level of crystallinity. PP generally have been used for binder that holds the fiber in one piece. PP have flame resistance, high heat distortion temperature, dimensional stability, and transparency properties. The reinforced material increased the general mechanical properties of the matrix while the matrix holds the reinforcement. In fiber- reinforced polypropylene (FRP) composites, it composed of polypropylene (PP) matrix that keeps the fibers in the orientation and desired location. Fibers are the main source of strength and the reinforcement protected by PP from external damages (Shubhra et al. 2013).

2.6 Thermal insulation

Thermal insulation is a combination of materials or a material that are applied to decrease the rate of heat transfer by radiation, convection, and conduction due to high thermal resistance (Pasztory et al. 2011).

2.6.1 The advantages of thermal insulation

The usage of thermal insulation in a building can help to reduce the dependence of electrical or mechanical system that operating in the building. As economy benefits, the usage of thermal insulator can help to achieve a great energy savings. Thermal insulation in the building can reduce the noise disturbance from the outside, as well as achieving indoor thermal comfort.

CHAPTER 3

METHODOLOGY

3.1 Introduction

For this research, the method used and several stages will be explain further in this chapter regarding the fabrication method that has been used in this experiment, and the experimental setup that has been used to get the data for the experiment

3.2 Raw materials

The materials that used in this project is kenaf core fiber powder and Polypropylene (PP) as the matrix materials. The ratio formulation for kenaf powder and PP is divided into composition ratio as stated in the Table 3.1-a:

Table 3.2-a: Ratio formulation of kenaf/PP

Sample	Kenaf powder (wt.%)	PP(wt.%)
1	0	100
2	10	90
3	20	80
4	30	70
5	40	60

3.3 Apparatus

The apparatus that used to perform the experiment is Philips Infrared Lamp, internal mixer machine, crushing machine and hot press machine.

3.4 Kenaf powder treatment

The treatment process of kenaf powder as follows. The kenaf powder is washed with distilled water and boiled at 100°C of water temperature for around 1 hour. Next, it will undergo the soaking process for 2 hours with about 2% of concentration Sodium Hydroxide (NaOH). Then the compound is left in the environmental chamber for 3 hours and cleaned by using normal pipe water. To ensure there is no more residual of NaOH at the kenaf powder, the washing process is repeated up to 4 times. The next process is the kenaf powder is drying process where it is put under the sunlight for 24 hours, 3 days.

3.5 Composite fabrication

The kenaf powder and PP is weigh as shown in the Table 3.1-a. By using a Thermo Haake Rheomix 600 OS internal mixer (Figure 3.5-a), the thermal mixing process at the rotor speed of 50rpm for 10 minutes and at a temperature of 175°C. This process will mix the kenaf powder and PP into uniformly. After that, the materials will be going into crusher machine. This process is to produce a standard granules size at 2 mm x 2mm. The final step to produce kenaf composite is by hot pressing process. The granules are filled in the pattern provided by lecturer and undergo hot pressing under 175°C for 8 minutes and cooled at the room temperature. Figure 3.3-b shows the schematic process of hot pressing unit. Figure 3.3-a shows the internal mixer machine type that used to mix the kenaf powder and PP. The final products in the form of board with the dimension of 240mm length, 180 mm of width and 5mm of height.

Figure 3.5-a: Thermo Haake Rheomix 600 OS internal mixer

Figure 3.5-b: Crushing machine

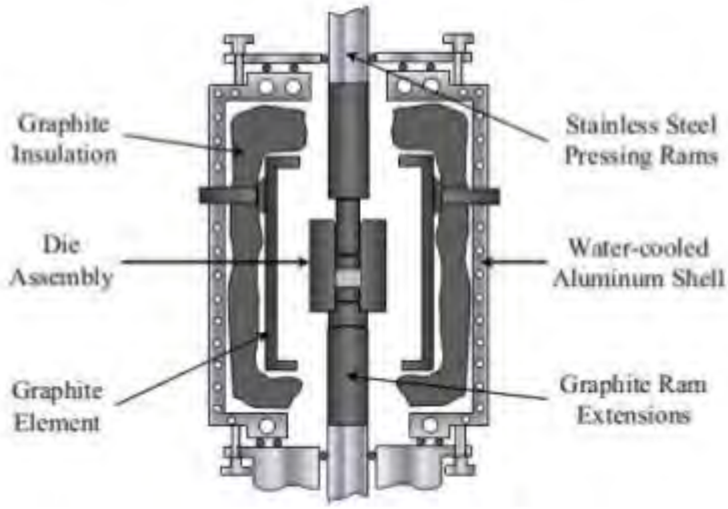

Figure 3.5-c: Hot Press Unit (Behera, 2016)

3.6 Thermal conductivity measurements

The purpose of this experiment is to get the thermal conductivity of the composite material. The specimens were heated by using infrared light radiation at 150Watt power supply. The temperature T_1 and T_2 are measured by using infrared thermometer at 30mm of distance and 90 degree of angel of attack to the board for every 30 seconds until 420seconds. The heat flow is determined from the electrical power supply of the infrared lamp. Figure 3.6-a shows the infrared thermometer that has been used to read the temperature of T_1 and T_2 of the specimen and Figure 3.6-b shows the Philips infrared lamp 150W (HP3616 model) that is used to supply heat to the specimens. Figure 3.6-c shows the experiment setup that has been used to run the experiment. The infrared lamp position at the distance of 35cm from the specimen and the electric power of the lamp is 1. The specimen is heated about 6 minutes and the temperature is recorded in the table for every 30 sec.

Figure 3.6-a: Infrared thermometer

Figure 3.6-b: Philips infrared lamp 150W HP3616

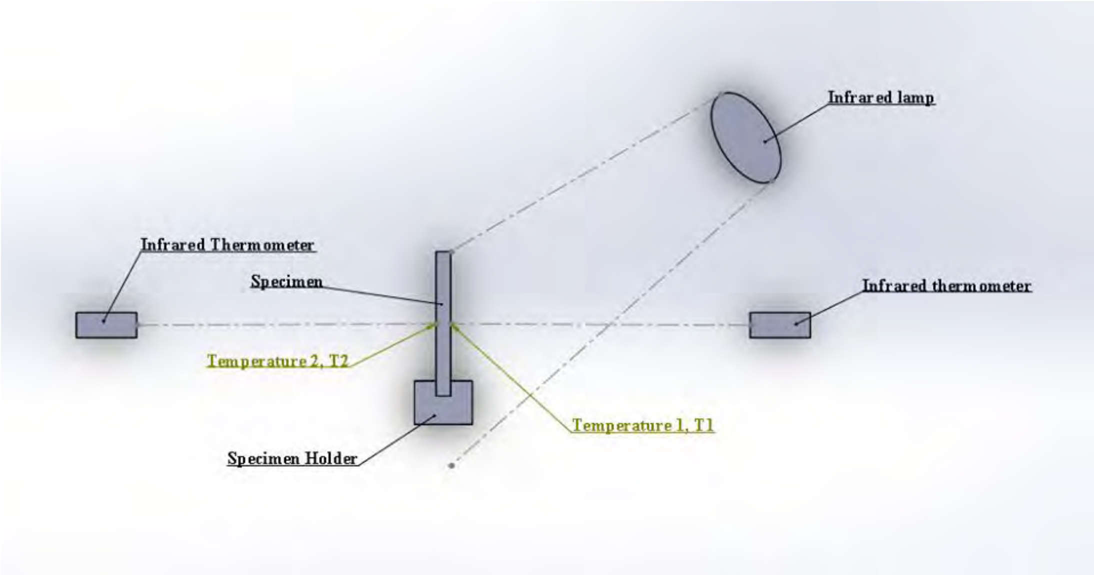

Figure 3.6-c: Experiment setup to determine the temperature difference of the specimen

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, the results and observations are obtained from the experiments. All the results will be explain further. The result of thermal conductivity and the sample of fabrication will be reported in this chapter.

4.2 Fabricated samples

Figure 4.2-a shows a fabricated specimen for 100% PP. The colour of the 100% PP specimen is cloudy white. The dimension of the specimen is follow to the desire dimension which is 240mm X 180mm X 5mm. Figure 4.2-b, Figure 4.2-c, Figure 4.2-d and Figure 4.2-e shows the fabricated specimens for 10:90 kenaf to PP, 20:80 kenaf to PP, 30:70 kenaf to PP, and 40:60 kenaf to PP respectively.

Figure 4.2-a: 100 (wt.%) PP specimen

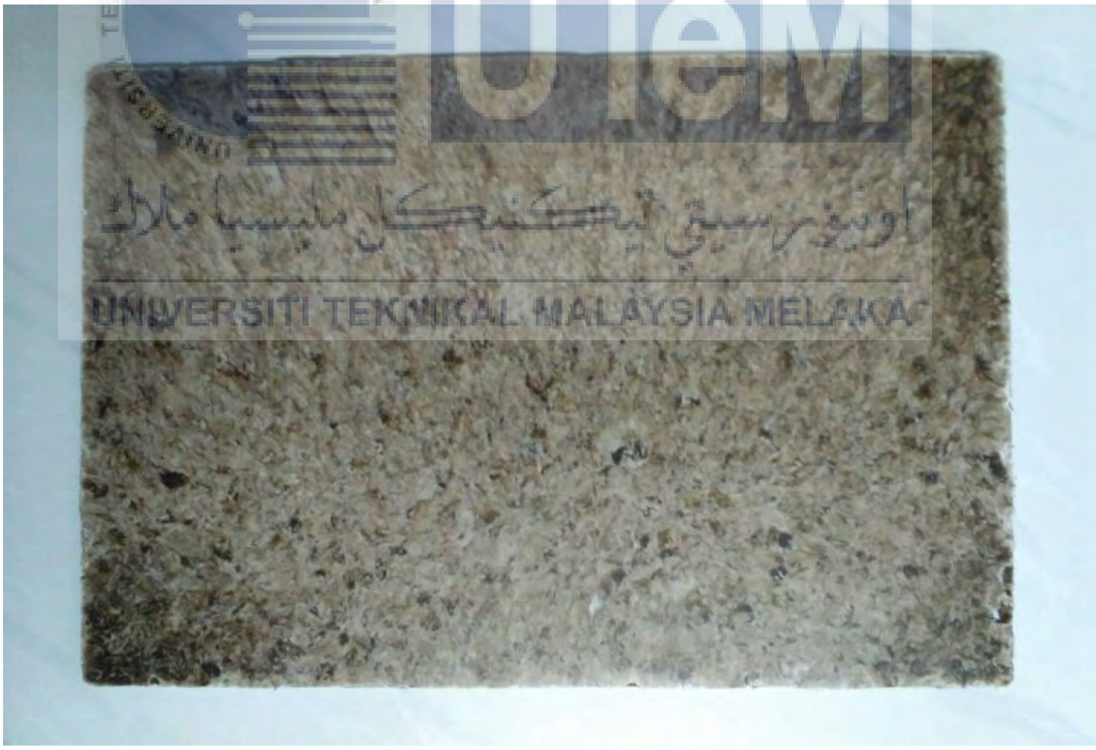

Figure 4.2-b: 10 (wt.%) kenaf to 90 (wt.%) PP specimen

Figure 4.2-c: 20 (wt.%) kenaf to 80 (wt.%) PP specimen

Figure 4.2-d: 30 (wt.%) kenaf to 70 (wt.%) PP specimen

Figure 4.2-e: 40 (wt.%) kenaf to 60 (wt.%) PP

4.3 Temperature distribution on fibre composite

The experiment is conducted in the ambient temperature of 32.7°C. From the table 4.3-a, we observed that there is slightly change in temperature between T_1 and T_2, and the temperature difference remain steady after 360s. From the whole heating process, T_2 increased from 35.0°C to 42.6°C which is it increased up to 7.6°C in 7 minutes.

Table 4.3-a: Temperature distribution on 100% PP

Time, t (s)	Temperature 1, T_1 (°C)	Temperature 2, T_2 (°C)
0	35.0	35.0
30	37.4	35.8
60	38.2	36.4
90	40.0	36.6
120	41.2	37.0
150	41.6	37.8
180	42.8	38.6
210	43.8	39.4
240	44.0	39.8
270	45.0	41.2
300	45.2	41.4
330	45.6	41.6
360	46.6	42.6
390	46.6	42.6
420	46.6	42.6

From the tabulated data in table 4.3-b, the temperature difference achieves it steady state at 360s, after 6 minutes undergoing the testing process. The T_2 roses from 34°C at the beginning to 47.4°C after 7 minutes, which is it has increased up to 13.4°C

Table 4.3-b: Temperature distribution on 90% PP to 10% Kenaf

Time, t (s)	Temperature 1, T_1 (°C)	Temperature 2, T_2 (°C)
0	34.0	34.0
30	39.0	36.0
60	40.6	37.6
90	42.6	40.8
120	42.6	41.8
150	46.2	43.8
180	47.2	44.2
210	48.8	45.6
240	50.4	45.6
270	50.4	45.8
300	51.8	46.8
330	52.0	47.2
360	52.8	47.4
390	52.8	47.4
420	52.8	47.4

Table 4.3-c shows that the tabulated data from the specimen of 80%PP to 20%Kenaf. The temperature difference enters steady state condition after 6 minutes. T_2 increased from 34.4°C to 48.2°C.

Table 4.3-c: Temperature distribution on 80% PP to 20% Kenaf

Time, t (s)	Temperature 1, T_1 (°C)	Temperature 2, T_2 (°C)
0	34.4	34.4
30	38.8	36.6
60	42.6	38.8
90	44.8	40.0
120	46.6	42.4
150	48.2	43.8
180	49.4	45.2
210	50.8	46.2
240	51.6	46.8
270	51.6	47.4
300	53.4	48.0
330	54.0	48.6
360	54.6	48.2
390	54.6	48.2
420	54.6	48.2

From the data recorded in Table 4.4-d, we found that the temperature difference start to stable at 360s during the test. Start from 6 minutes, T_1 and T_2 were maintaining at same temperature difference. Besides, all the temperature recorded were not exceeding 60°C.

Table 4.3-d: Temperature distribution on 70% PP to 30% Kenaf

Time, t (s)	Temperature 1, T_1 (°C)	Temperature 2, T_2 (°C)
0	34.0	34.0
30	40.2	36.2
60	44.4	37.8
90	47.8	38.8
120	49.8	40.2
150	51.8	43.0
180	53.4	43.4
210	54.8	44.0
240	55.8	45.8
270	56.6	46.4
300	57.2	47.0
330	57.8	47.4
360	57.8	47.4
390	58.4	48.0
420	58.4	48.0

Table 4.3-e shows that T_2 were increase slowly for the first 2 minutes and the temperature difference remains steady after 6 minutes. These shows that all the specimens are homogenous. The tabulated and recorded data can be use for the further calculation.

Table 4.3-e: Temperature distribution on 60% PP to 40% Kenaf

Time, t (s)	Temperature 1, T_1 (°C)	Temperature 2, T_2 (°C)
0	34.2	34.2
30	39.6	34.2
60	42.4	34.6
90	44.8	34.8
120	46.4	35.0
150	47.6	35.8
180	49.2	36.2
210	50.4	36.8
240	51.2	37.8
270	52.2	38.4
300	52.8	39.0
330	53.6	39.6
360	54.8	40.0
390	54.8	40.0
420	54.8	40.0

4.4 Sample calculation

Density of the fibre composite:

$$\rho = \frac{m}{v}$$

$$= \frac{0.157kg}{0.0216m^3}$$

$$= 716\, {}^{kg}/_{m^3}$$

Thermal conductivity of the fibre composite:

$$k = \frac{Q}{A} \times \frac{L}{\Delta T}$$

$$= \frac{150W}{0.0414m^2} \times \frac{0.005m}{4K}$$

$$= 4.213W/mK$$

All the calculated density, temperature difference and thermal conductivity of the composite has been shown in the table 4.4-a.

Table 4.4-a: Thermal conductivity of composite at different proportion of kenaf to PP

Sample	Density of the composite, ρ (kg/m^3)	Kenaf Powder (wt.%)	PP (wt.%)	Temperature Difference, ΔT (K)	Thermal conductivity of composite, k (W/mK)
1	731.57	0	100	4	4.5290
2	716.11	10	90	5.4	3.3548
3	787.68	20	80	6.4	2.8306
4	810.28	30	70	10.4	1.7419
5	845.83	40	60	14.8	1.2241

From the constructed figure 4.4-a, we can see that the thermal conductivity decrease as the content fibre in the composite increase. As we can see, the thermal conductivity is highest which is at 4.5290 W/mK when there is no kenaf fibre inside the composite and the thermal conductivity is at the lowest which is at 1.2241 W/mK when the composition of kenaf fibre is 40% form the fabricated composite. This shows that the increasing in kenaf fibre wt.% in composites showed decreasing in the thermal conductivity of the composites. This has to do with the porosity of the composites. The porosity in the composites increased as the fibre content in the composites increase resulting the thermal conductivity decreasing. As the content fibre in the composite increase, the density also increase which is resulting the increase of the porosity. This may be due to the fibre particles and the polypropylene are not totally contact closely at each other interface, resulting the higher porosity at the higher fibre content. Furthermore, the polypropylene may not able to fill all the space or voids that was formed between the fibre particles due to poor flowability of the polypropylene at the high content of the fibre. According to theory, heat is transferred by using conduction, convection and radiation. In this experiment, the heat was transferred by using conduction in the fibre composite. As the porosity increased, more air were traps inside the fibre composite making its poor heat conductor as air is a poor heat conductor. As the fibre composite gets hot, the molecule will expand and the fibre particles are further apart, takes time to conduct the heat as there are more voids in high porosity fibre composite, making the thermal conductivity to decrease.

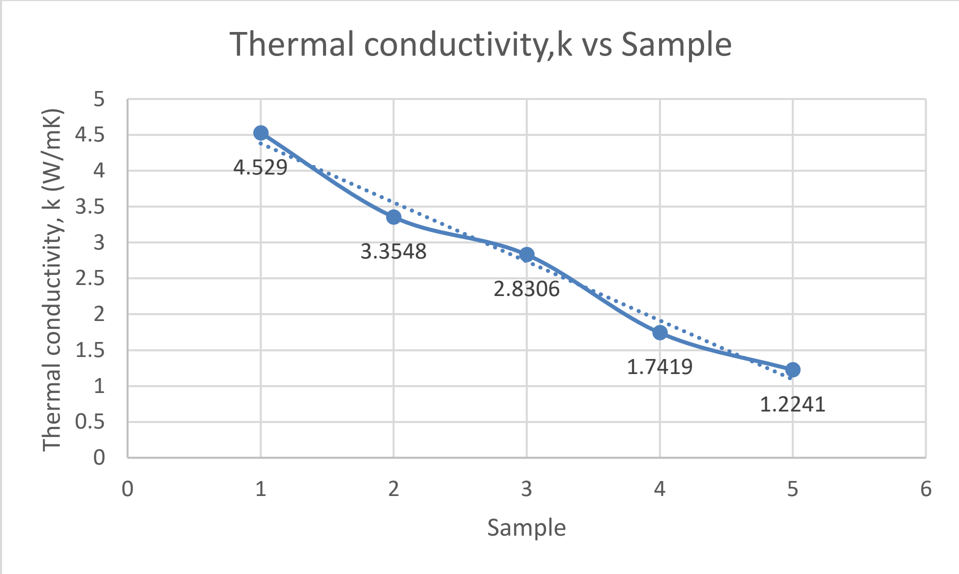

Figure 4.4-a: A graph of thermal conductivity of sample vs sample

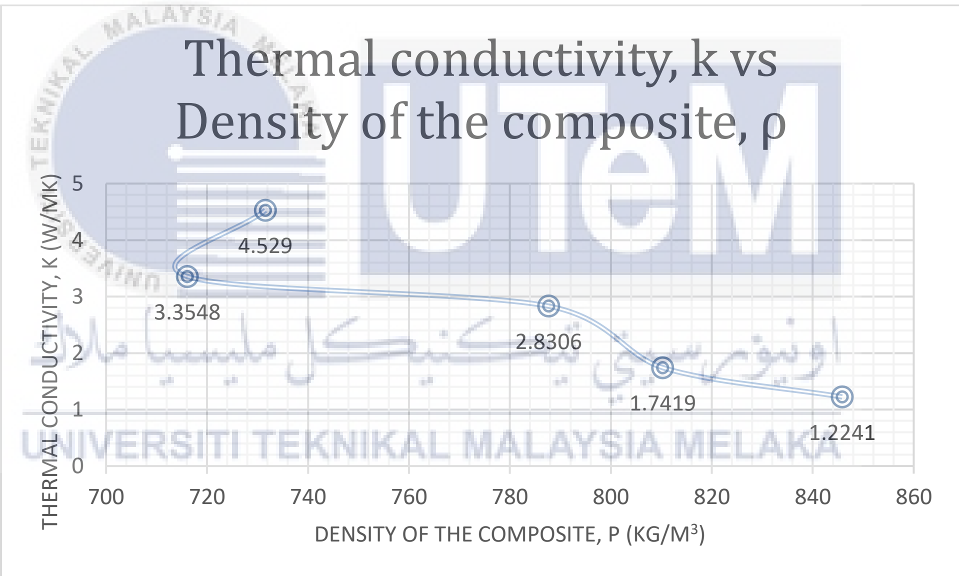

Figure 4.4-b: A graph of thermal conductivity vs density of the composite

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Introduction

This chapter will be divided into two parts. The first part is to conclude the findings that has been carried out during the experiments and the second part is the recommendation for further discussion and study that should been done in order to increase the quality of the research in the future.

5.2 Conclusion

In this study, the objectives earlier are to study the thermal properties of different ratio of fibre/polypropylene, to obtain the thermal properties of kenaf composite and to provide a complete analysis of thermal conductivity of kenaf composite. There are 5 specimens that have been studied in this experiment; 100% PP, 10 wt.% kenaf to 90 wt.% PP, 20 wt.% kenaf to 80 wt.% PP, 30 wt.% kenaf to 70 wt.% PP, 40 wt.% kenaf to 60 wt.% PP. From the observation results and tabulated data, the 10wt.% kenaf to 90 wt.% PP composites has highest thermal conductivity among the composite materials due to low porosity and the 40 wt.% kenaf to 60 wt.% PP composites material has highest porosity, resulting in lowest thermal conductivity as the porosity is influencing the thermal conductivity property of the composite material.

5.3 Recommendation

Composites materials may have large advantages over compact steel in the motor vehicle which is making the car lighter, more saving on fuel consumption and safer. They also do not rust like steel on the body of the car, which is has been used as thermal insulator in the door.

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