Faculty of Mechanical Engineering

THERMAL INSULATION MATERIAL MADE FROM KENAF COMPOSITE

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SUPERVISOR'S DECLARATION

I hereby declare that I have read this project report and it is sufficient in terms of scope and quality for the award of the Bachelor of Mechanical Engineering.

Signature :..

Name of Supervisor :Shamsul Bahari Bin Azraai

Date :..

DECLARATION

"I hereby declare that the work in this report is my own except for summaries quotations which have been duly acknowledged."

Signature : ………………….

Author : Chong Yung Oon

Date : …………………..

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ABSTRACT

This project focus on using experimental methods to determine the properties of thermal insulation material made from kenaf composite. The kenaf composite is made of kenaf powder and polypropylene (PP) pellets but divided to four different proportion, which are 20% Kenaf 80% PP, 30% Kenaf 70% PP, 40% Kenaf 60% PP and 50% Kenaf 50% PP. The properties of material to be obtained from the experiment include of thermal conductivity, tensile strength and flexural strength. Experiment stage consists fabrication of specimen, fitting of specimen and testing of specimen. From the results, the thermal insulation properties of composite directly proportional to the natural fiber content. As the kenaf content increase, the thermal insulation properties of composite also increase. Tensile and flexural strength of kenaf composite were improved when compared to the raw material. Overall, the composite with the proportion of 30% Kenaf 70% PP showed the highest average properties compared to other proportions. It had been selected as most suitable proportion of kenaf composite to be used as thermal insulation material.

ABSTRAK

Projek ini menumpukan kepada penggunaan eksperimen untuk mencari sifat bahan penebat haba yang diperbuat daripada komposit kenaf. Komposit kenaf diperbuat daripada serbuk kenaf dan polipropilena (PP) tetapi dibahagikan kepada empat bahagian yang berlainan iaitu 20% Kenaf 80% PP, 30% Kenaf 70% PP, 40% Kenaf 60% PP dan 50% Kenaf 50% PP . Sifat-sifat bahan yang diperolehi daripada eksperimen termasuk kekonduksian terma, kekuatan tegangan dan kekuatan lenturan. Peringkat eksperimen terdiri daripada fabrikasi spesimen, pemotongan spesimen dan pengujian spesimen. Daripada hasilnya, sifat penebat haba komposit yang berkadar langsung dengan kandungan serat semula jadi. Apabila kandungan kenaf meningkat, sifat penebat haba dalam komposit juga meningkat. Kekuatan tegangan dan lenturan komposit kenaf bertambah baik apabila dibandingkan dengan bahan mentah. Keseluruhannya, komposit dengan nisbah 30% Kenaf 70% PP menunjukkan sifat purata tertinggi berbanding dengan bahagian lain. Ia telah dipilih sebagai nisbah yang paling sesuai bagi komposit kenaf untuk digunakan sebagai bahan penebat haba.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

NF	Natural Fiber
KF	Kenaf Fiber
KBF	Kenaf Bast Fiber
PP	Polypropylene
SEM	Scanning Electron Microscope
CMC	Ceramic Matrix Composite
MMC	Metal Matrix Composite
PMC	Polymer Matrix Composite
rPP	Recycled Polypropylene
KPNC	Kenaf and Polypropylene Nonwoven Composite
KBFB	Kenaf Bast Fiber Bundle
MH	Magnesium Hydroxide
RPM	Revolution Per Minute
TGA	Thermogravimetric Analysis

LIST OF SYMBOLS

$\boldsymbol{k}$	=	Thermal Conductivity
Q	=	Amount of Heat Transfer
t	=	Time
A	=	Cross-sectional Area
Δ**T**	=	Temperature Difference
d	=	Length/Thickness
E	=	Young's Modulus
F	=	Force
L_o/ℓ_o	=	Original Length
L_n/ℓ	=	New Length
σ	=	Stress
ε	=	Strain
e	=	Elongation
I	=	Current
V	=	Voltage
Δ**X**	=	Length Difference
R	=	Rate of crosshead motion, mm/min
L_s	=	Support Span, mm
D_b	=	Depth of Beam, mm
Z	=	Rate of Straining of the Outer Fiber

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Global resources are draining very fast and some of them may facing extinct problem not far in the future. Human traced out this problem and provide a solution to shift to renewable resources. Renewable resources attract the attention from everyone and become preferred choice for public after on. This is because renewable resources can never use up and friendly toward environment. Concept of green enable public to concern more about environment than concern about social fields (German Polish Ukrainian Society, 2017). A lot of green products are made using the renewable resources to reduce the pollution to environment. This is because green products are biodegradable which will not left after certain time.

Natural fibers (NFs) from renewable resources such as kenaf bast fiber (KBF) is very good material option to create green product. Kenaf (Hibiscus cannabinus, L. family Malvaceae) is seen as an herbaceous annual plant that can be grown under a wide range of weather condition. Kenaf is easy to get from market and the price is affordable. It can use to reinforce with binder to create a bicomposite thermal insulation material. Thermal insulation defined as the progress of insulation against transmission of heat (Merriam-webmaster, 2017). This means reinforced kenaf composite is a useful invention under green concept which provide conveniences to human and upgrade the human living quality. This product is then used in construction sector to improve the building energy management.

Polypropylene (PP) is a common use binder for kenaf bast fiber to be reinforced into thermal insulate material. Among binder option, polypropylene is chose because it got very low thermal conductivity. Low thermal conductivity indicate it is very good thermal insulator as it blocks heat energy to penetrate through it.

As kenaf bast fiber reinforced with polypropylene, a green concept product, kenaf composite with better thermal insulation properties is created. However, the thermal insulation properties of this kenaf composite has slightly different for the different portion of the materials. The proportion for the kenaf bast fiber and polypropylene directly affect the thermal conductivity of kenaf composite.

Generally, kenaf composite is a very useful green product. It is biodegradable which mean it might totally compost after some time. Most of the time kenaf composite is produced in the industry in large scale. The materials need to go through some manufacturing process such as hot mixing, grinding and hot pressing before become complete product. This kenaf composite is widely used in construction to block the heat energy from outdoor transmit into indoor. It was use as roof material or wall mounting material.

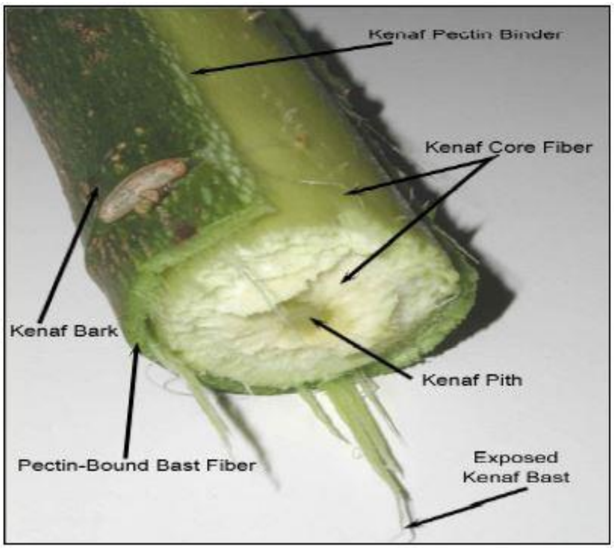


Figure 1.1 Exposed Physical Appearance of Kenaf

1.2 PROBLEM STATEMENT

Global warming issue is not a surprising news. The problem is the global temperature still rising all the time. This situation has caused outdoor temperature to have significant difference when compared to indoor temperature especially for hot season country. Malaysia is a hot season country which located at the equator of the earth. Heat energy from the sun is directly irradiate to building outside. When the outdoor temperature rises due to hot weather, the human stay in indoor would also feel uncomfortable because the heat energy from outside will definitely transmit into indoor in term of conduction, convection and radiation. Rooftop and wall are the most common substances that could transmit heat from outside into inside after exposed to sunlight for a long time. Thermal insulation is needed for building to prevent transmission of heat from outdoor to indoor. By acquiring the thermal insulation material at outer face of building, the heat transmitted to indoor is believe to be reduce. Human who stay in not comfortable surrounding is hard to achieve any productivity. Here come the problem. What is the material that suitable to use for building construction? What is the properties that should behaved by this material in order to achieve requirement of a building construction material?

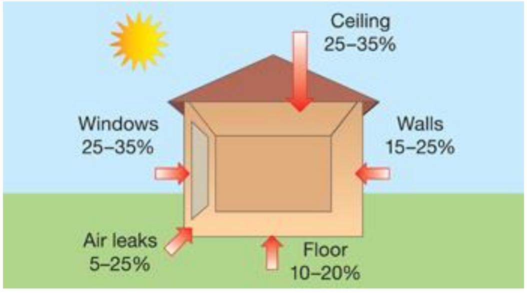


Figure 1.2 The Way House Gain Heat from Sun.

1.3 OBJECTIVE

The objectives of this project are as follow:

1. To determine and compare the Thermal Conductivity Value, *k* of kenaf composite for different proportion of composite materials.
2. To determine and compare the Tensile Stress of kenaf composite for different proportion of composite materials.
3. To determine and compare the Flexural Stress of kenaf composite for different proportion of composite materials.
4. To compare the experimental results to the previous results stated in journals.

1.4 SCOPE OF PROJECT

The scopes of this project are:

1. Fabricate kenaf composites for different proportion of composite materials.
2. Testing and comparing kenaf composite for different proportion of composite materials on thermal conductivity.
3. Testing and comparing kenaf composite for different proportion of composite materials on tensile strength and flexural strength.
4. Summarise and propose a best kenaf composite to use as thermal insulation material.

CHAPTER 2

LITERATURE REVIEW

2.1 NATURAL FIBER

Natural fibers are string type of substances like thread made by plants and animals. Most of the time, these fiber derived from specifically grown textile plants and fruit trees. Common source of natural fibers can be gained from some plant. For example, coconut, cotton, flax, hemp and kenaf. The benefit of natural fiber is it do not harm environment as it is biodegradable. Natural fibers are use to reinforce or filler material in the fabrication of composites. This is because public interest toward environmental has increased a lot. Human race found out the problem and thinking of use sustainable materials to replace non-renewable source (Bajuri, Mazlan, Ishak, & Imatomi, 2016).

Commonly, natural fiber could be classified based on their source of origin which are animal, plant and mineral. Animal fiber is commonly made from grandular secretion of some insects such as silk. It composed molecular structure material such as keratin. Plant fiber is made of cellulose, which has circular cross section and elongated structure. Plant fiber can be classified to seed fibers, stem fibers, leaf fibers and fruit fibers. Mineral fibers made of fibrous structure which is normally found in mineral such as rock.

When doing comparison among animal, plant and mineral fiber, plant fiber is the most famous and common use. This may due to advantages of plant fiber such as abundance, low cost and low density. It also can absorb carbon dioxide from the environment, renewability and biodegradability which is considered as eco-friendly. However, the disadvantages of this plant fiber still exist. Plant fiber has low thermal stability, lower mechanical properties, low resistance to microorganism and high moisture absorption (Fibrenamics, 2017).

2.2 KENAF

As one of the natural fiber, kenaf is fiber plant native to east-central Africa when it has been grown for thousands year for the purpose food and fiber. Kenaf, is known as Hibiscus cannabinus species, which is a fast growing plant. Kenaf started to be known in late 18th century. After kenaf is known, it was encouraged to be cultivate and produce in large scale during World War II (Encyclopaedia Britannica, 2017).

Kenaf can grow up to 18 feet (5.5 meters) in height and its fiber concentrated mainly at lower part. Kenaf is strong and tough plant. It can grow in very uncomfortable environment, and able to adopt many different types of soil.

Kenaf is new trading material in international. Thus, its demand in market is still not so high. However, high yield rate of kenaf become one of the option of trader.

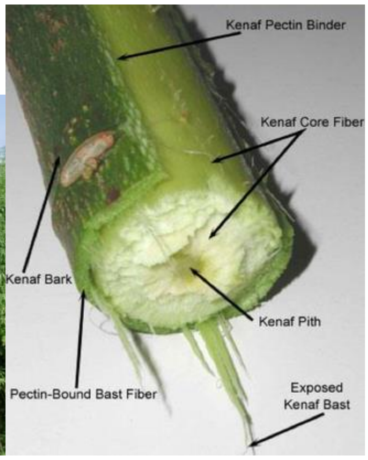


Figure 2.1 Kenaf Plant Field   Figure 2.2 Kenaf Structure (kencoind, 2017)

Kenaf is an herbaceous annual plant that can grow in any weather conditions, and it has been dominated to use as rope and other things. Kenaf has been deemed extremely environmentally friendly for two main reasons; (a) it congests carbon dioxide at a significantly high rate and (b) it absorbs nitrogen and phosphorous from the soil. In additional, kenaf, displays the properties same to other natural fibers, includes low density, high specific mechanical properties, and is easily recycled (Zampaloni et al., 2007).

A study was conducted on mechanical properties of kenaf-polyesters composite. According to this study (My, Pt, Ip, & Ar, 2011), they used and tested kenaf fiber as a high potential reinforced material in thermosets and thermoplastics composites. Modification is required and mechanical properties for composites product can be further improved by doing some research. The efficiency of the fiber-reinforced composites also depends on the manufacturing process. In their research, polyester resin, sodium hydroxide (NaOH), and kenaf fiber that needed to go through the retting process were prepared. Kenaf fibers were soaked in five different chemical solution for different chemical treatment.

Table 2.1: The Chemical Solution of the Treatment

Treatment	NaOH (%)	Soaking time, (hr)
1	3	12
2	3	24
3	6	12
4	6	24
5	9	12

The fibers were washed after soaked in sodium hydroxide solution and dried for 24 hours. Composite was produced by vacuum infusion. The mount for the composite was 300 x 300 mm. Spiral tube was fitted at resin feed lines and a releasing agent was sprayed evenly onto the surface of the mould. Four layers kenaf fiber were placed on the mould with different of two direction, 0 ° and 90 °. Peel ply, distribution media and vacuum bag were placed. Vacuum pump used to empty the air. The leaking check is occurred. As there is no leaking found, the polyester resin was infused to the system. Figure 2.3 shows the vacuum infusion setup and process.

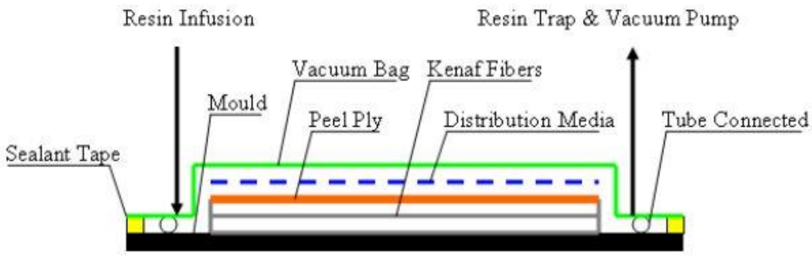


Figure 2.3 The Vacuum Infusion Configuration

Physical characteristic of the fibers can be determined by scanning electron microscope (SEM) machine model Zeiss Evo 50. Tensile test, flexural test and izod impact test were done on composites referred to standards ASTM D638-01, ASTM D790 and ASTM D256. The results showed that impurities were clearly observed on the surface of untreated fiber. Use of sodium hidroxide (NaOH) in the modification of fiber by were effective in removed the impurities of the fiber surface. Almost all impurities have been remove from the fiber surface. However, long soaking time in of kenaf in NaOH damaged the fiber surface. The untreated kenaf fiber composites showed low tensile strength of 49.1 MPa. The tensile strength increases as the NaOH concentration in fibers increased. However, the tensile strength decreased when the concentration of NaOH was increased up to 9%. For the flexural strength, the highest (93.4 MPa) flexural strength was resulted at treatment of 9% NaOH composite.

2.3 POLYPROPYLENE

Polypropylene (PP) is a plastic, or scientifically called as thermoplastic. In chemical field, it is actually a long chain containing repeating unit of propylene molecule. It has a very wide application either in industrial sector or commercial as it can be easily melt and used to pack products. It was first introduced in 1951 by scientists named Paul Hogan and Robert Bank (Creativemechanism, 2017).

Polypropylene (PP)'s popularity has been expanded in 1954 since Italian chemist succeed to perfect and synthesize first polypropylene resin. It started to dominate the market in global. Its demand still in growing trend. This may due to its advantages such as easy to produce, high flexural strength, good electric insulator and good fatigue resistance. A disadvantage of polypropylene is only can heat up for once. It will burned if heated for second time.

The chemical formula for polypropylene is $(C_3H_6)_n$. Its melting temperature is 130 ℃. It has tensile strength and flexural strength of 32MPa and 41MPa respectively. It is now a widely use material for composite which reinforced with fiber to manufacture a thermal insulation material for building construction.

2.4 COMPOSITE

Composites are consists of two or more different materials combined together in order to enhance the properties of the original substance (Bcomp, 2017). These materials can be considered as physical and chemical properties combined, but in specifically they remain detach and different at certain level because they do not fuse into each another.

Composite matrix materials are divided into three categories, which are ceramic matrix, metal matrix and polymer matrix (AZoM, 2017). Ceramic matrix composites (CMC) are a group of composite which ceramic fiber is embedded into the ceramic matrix forming ceramic reinforced fiber composite (CRFC) material. CMC materials were invented to solve the problem such as brittleness, limited thermal shock resistance and low fracture toughness. Metal matrix composite (MMC) are the composite materials which have two and above constituent parts. At least one of the constituent part is metal while another one can be metal or different material. Strength of composite was enhanced when the metal matrix is reinforced. Hybrid composite is the composite with three or above constituent parts. Light metal such as magnesium and aluminum are used for matrix in structural applications while cobalt is used for high temperature applications. The benefit of metal matrix composites are possess high electrical and thermal conductivity, do not absorb moisture and good fire resistant. Polymer matrix composites (PMC) can be split into three types, namely thermoset, thermoplastic and rubber. Polymer is a long chain molecule consist of repeating structure. They made up by simple manufacturing process and very low cost. Advantages of polymer matrix composite are low density, high corrosion resistance and strong electricity insulator.

Other than matrix material, composites are able to classify according to the geometry as particle reinforced, fiber reinforced, sandwich and laminate type. The tree diagram and definitions are stated as below.

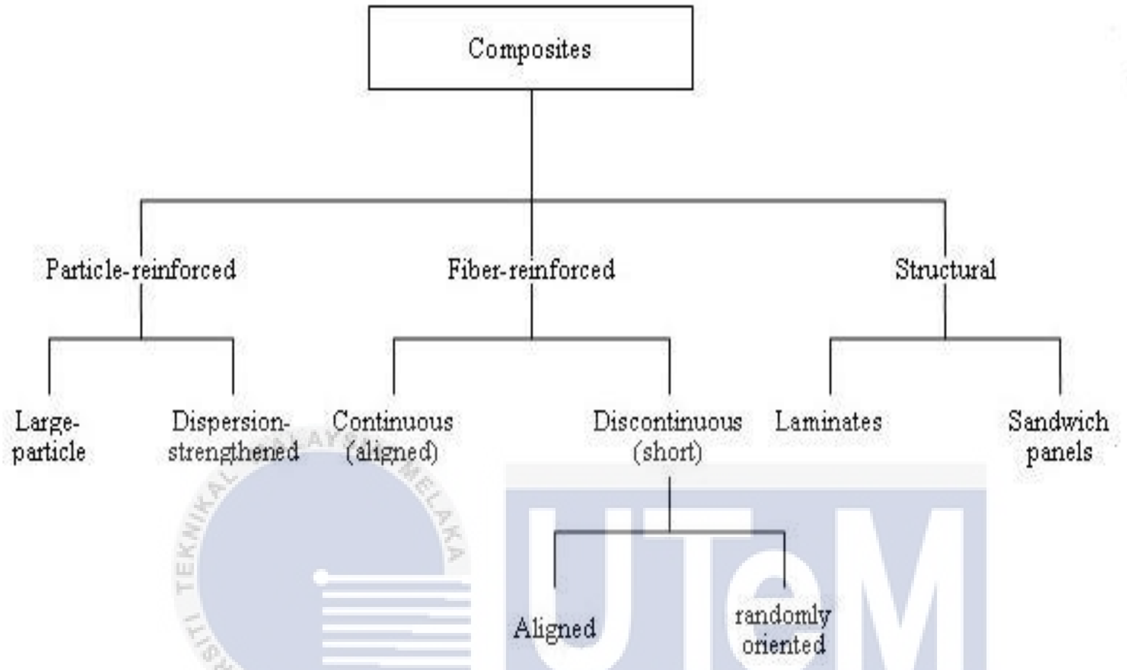
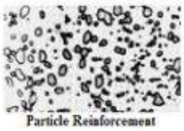
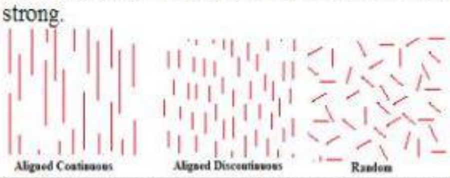


Figure 2.4 Geometry Classification of Composite (EngineerCivil, 2017)

Table 2.2 Type of Composites and Applications (EngineerCivil, 2017)

Sl. No.	Type of Composite	Application
1	Particulate Composites are composed of particle of one or more material is suspended in a matrix of another material to make the material stronger. 	For example wood particle boards, in concrete the particle of sand or rock bound together by a mixture of cement and water. used as fillers to improve strength, toughness, processibility, dimensional stability, frictional wear and lubrication properties, and, in some cases, resistance to ultraviolet radiation.
2	Fiber Reinforced Composites are the long fiber of one material is embedded in the matrix of other material which turns out to be extremely strong. 	These FRC can be used as bulletproof vests where crisscross system of fibers is used. Is used in concrete by reinforcing elements like carbon fiber, aramid fiber, grid type reinforcement elements, etc. Add reinforcing steel rods, wires and bars (rebar) to uncured concrete to enhance mechanical strength. .
3	Sandwich Composites or Laminated composites are layers of two or more different material are bonded together by sandwiching two layers of strong 	The sandwich composites are used as Space shuttle heat panels. The decorative surface laminates are thick and bonded to wood offering improved heat and moisture resistance and allowing a wide range of decorative effects.

A research was conducted on the type of composites (Suharty, Ismail, Diharjo, Handayani, & Firdaus, 2016). These research wished to determine the effect of kenaf fiber as reinforcement material on the tensile, flexural strength and impact toughness properties of recycled polypropylene (rPP) composite. The samples was initially cleaned up, washed with ethanol and dried. Next, it was chopped in 2 x 2 mm. The KF cut to 5 mm size, then soaked in NaOH 4% for 24 hours. The halloysite powder was sieved and calcinated at furnace for 1 hour. Then, it was let for 24 hours. All starting materials were solved in boiled xylene and mixed perfectly for 1 hour. The mixing product was evaporated and released the xylene to form masterbatches composite. Then, it was hot pressed for 20 minutes at 180 ℃

to produce the specimens for mechanical test. Table 2.3 showed the composition of four different composites.

Table 2.3 Formulation of rPP/Hall, rPP/KF and rPP/KF/Hall Composites

Ingredients	Compounds			
	C0	C1	C2	C3
rPP	100	65	65	65
DVB	-	0.1	0.1	0.1
PP-g-AA	-	15	15	15
Hall	-	20	-	20
KF	-	-	20	20

As new composites were produced, it was sent to do mechanical. In mechanical testing, ASTM D638 and ASTM D6272 were referred to complete the tensile test and flexural.

For the results, the tensile strength and flexural strength of rPP as raw materials showed 21.25MPa and 23.61MPa. Meanwhile, the tensile strength and flexural strength for C1, C2 and C3 are 32.32MPa and 26.07MPa, 34.26MPa and 31.11MPa, 38.28MPa and 33.48MPa respectively. In a nutshell, kenaf is a good reinforcement material because it can increase the mechanical strength such as tensile strength and flexural strength in composites.

Another research was conducted on kenaf and polypropylene(PP) nonwoven composites(KPNC) (Hao, Zhao, & Chen, 2013). The goal of this research was to explore the manufacturing conditions that the performance of natural fiber polymer composites in terms of mechanical properties, thermal stability, and acoustical behavior. These materials were treated before started experiment.

The kenaf fiber and PP fiber with 50/50 weight ratio were mixed fed into an F015D Universal Laboratory Carding Machine to produce a fiber web. The fiber web was carded once again in the perpendicular direction in order to improve web isotropy. After that, it was transferred to a Morisson Benkshire needle-punching machine in order to produce nonwoven felts. These sample were compression molded by the MEYER Transfer Printing and Labority Press System (Type APV 3530/16). After the molding process, samples were transferred to cold pressed. The 6- mm KPNC panels were then cut into specific sizes to fit the instrumental testing. In order to comply with ASTM D 3039 for polymer matrix composite materials, a MTS QT/5 Universal Tester was used to determine the tensile strength and modulus of the nonwoven composites. ASTM D790 was used as guide of three point flexural test. Ten specimens were tested for each sample to obtain a higher accuracy results.

Table 2.4 Tensile, Three-point Bending In-plane Shearing, and Impact Test Results of KPNCs

Tensile, three-point bending in-plane shearing, and impact test results of KPNCs.

Sample ID	Tensile modulus (MPa)	Flexural modulus (MPa)	In-plane shear modulus (MPa)	Impact strength (kJ/m^2)	Poisson's ratio
5/230/120	424(25)	306(11)	172(10)	2.94(0.45)[b]	0.23
5/230/60	347(21)	183(5)	139(8)	3.33(0.69)[b]	0.25
5/200/120	323(8)	177(6)	130(4)[a]	3.98(0.63)	0.25
5/200/60	300(15)	158(14)	124(5)[a]	9.70(0.85)	0.21
7/230/120	395(13)	356(28)	165(6)	3.16(0.28)	0.20
7/230/60	366(19)	273(22)	150(10)	3.78(0.64)[c]	0.22
7/200/120	340(6)	150(16)	135(10)	3.64(0.36)[c]	0.26
7/200/60	262(6)	108(13)	101(8)	9.00(1.70)	0.30

The sample ID is in the format of thermal press pressure ($x10^5$ Pa)/temperature (℃)/time (s). The Poisson's ratio is calculated from the formula of Young's modulus (E) and shear modulus (G), using equation m = E/ [(2 x G) -1]. For the 6-mm composites, sample moduli decrease in the order of X/230/120, X/230/60, X/200/120, and X/200/60 (X can be either 5 or 7).

The results of the research showed that the manufacturing conditions was unobvious in term of affecting the composite thermo-mechanical properties. KPNCs were more thermally stable than virgin PP plastics due to addition of kenaf fiber as reinforcement material.

2.5 THERMAL CONDUCTIVITY

What is thermal conductivity? The word thermal referred to the heat or heat energy and conductivity means the rate of transfer. In combination, thermal conductivity means the strength of transferring heat energy. High thermal conductivity means the good ability in conduct heat or transfer heat energy. The particle in substances vibrate vigorously and transfer the molecular kinetic energy to adjacent molecule with higher speed.

In simple definition, thermal conductivity refers to rate of heat transfer from a hotter region to cooler region in a body in term of achieving equivalence of temperature. Thermal conductivity is usually explained by using the concept of transfer of kinetic energy between molecules. The kinetic energy of a molecule stored in hot body is much higher than a molecule in cold body. When two molecule with different kinetic energy, the kinetic energy of molecule in hot body is transferring to the molecule in colder body. The molecule which receives the kinetic energy is now vibrates and moves more vigorously. The coherence molecule will then receive the kinetic energy and has same behavior as previous one. The cumulative effect of these collision between molecules, results in a net flux of heat transfer from hot body to cold body.

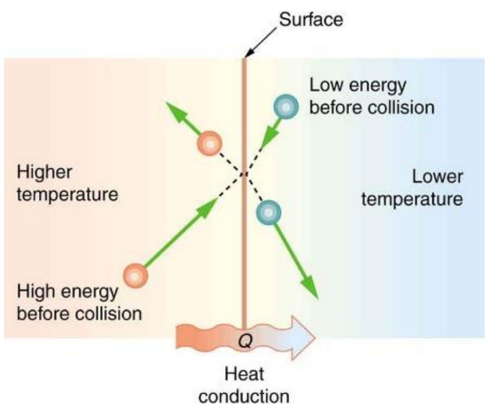


Figure 2.5 Heat Conduction by Collisions of Molecules (KHAN Academy, 2017)

There are few parameters affecting the rate of heat transfer, which are *k*, *A*, ΔT *and* *d*. These four factors are proved by experiments, and an equation was derived.

$$\frac{Q}{t} = \frac{kA\Delta T}{d} \quad \text{……………..…} \ (2.1)$$

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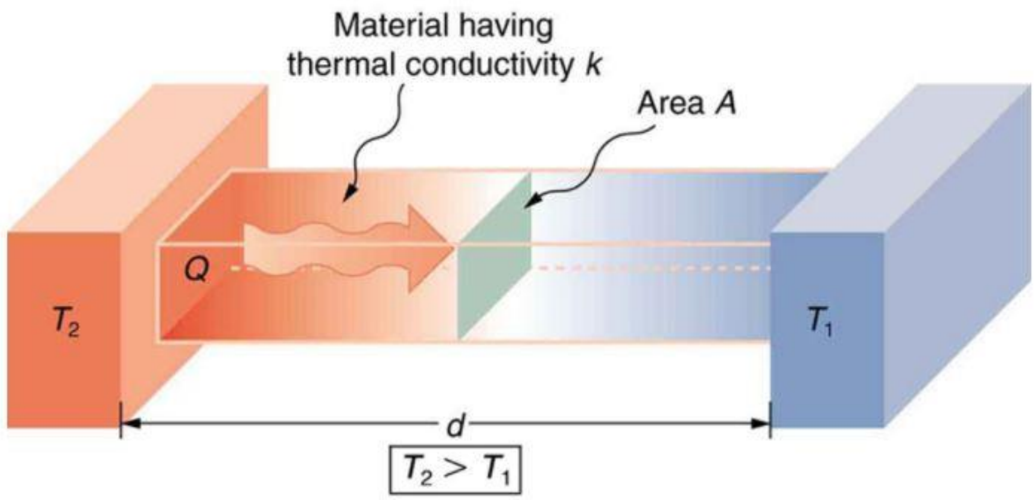

Figure 2.6 Heat Transfer from A Hot Region to Cold Region in A Material (KHAN Academy, 2017)

A research was done on the temperature and loading rate effects on tensile properties of kenaf bast fiber bundles (KBFB) and composites (Xue, Du, Elder, Wang, & Zhang, 2009). This research was considered as completed because the goal of understanding the fundamental mechanical properties of kenaf fiber bundles had achieved.

They did many different evaluation for the kenaf content composites. Kenaf stem and kenaf fiber epoxy strands are two different part of kenaf chosen in manufacturing the specimen. They had manufactured the specimen and fitted it to specific dimension. Researcher used ASTM C1557-03 as a reference in the term of doing tensile test and obtain young’s modulus. The gauge length for the machine was determined to be 20mm.The machine researcher used to do tensile test was Instron (Model 1011) universal testing machine. From the results gained, all the specimens showed higher modulus , higher tensile strengths and failure strains, indicating that failure occurred at multiple locations simultaneously along the KBFB. Most of the samples were treated according to the standard method before sent to test.. Results showed the temperature effects on tensile properties of kenaf bast fiber bundle are not much as the kenaf is natural fiber.

Another study was conducted on mechanical and thermal properties of kenaf fiber (KF) reinforced polypropylene (PP) and magnesium hydroxide (MH) composites (Lee, Sapuan, & Hassan, 2017).

These composites displayed a lot superior mechanical properties such as high crystallization temperature and higher storage modulus. MH is added to the composite as flame retardant filler because it is environmental friendly chemical. Sixteen sample of different compositions were prepared and dried. HaakeRheocord was used to melt and mix the materials at a temperature of 170 ℃ at 50 revolutions per minute (RPM) for a duration of 15 minutes.

After this, PP was inserted to the melted solution and heated for 5 minutes. Cooling agent and MH were added and mixed again for another 10 minutes. The specimen is fitted to specific dimension by following the standards. ASTM D638 was used as references to do the tensile test. Dumbbell specimens were cut out from the molded sheets using a die. Flexural testing was also conducted by using the Instron 5kN machine using the ASTM D790 testing standard. 10 samples were tested. Figure 2.7 and Figure 2.8 show results of experiment.

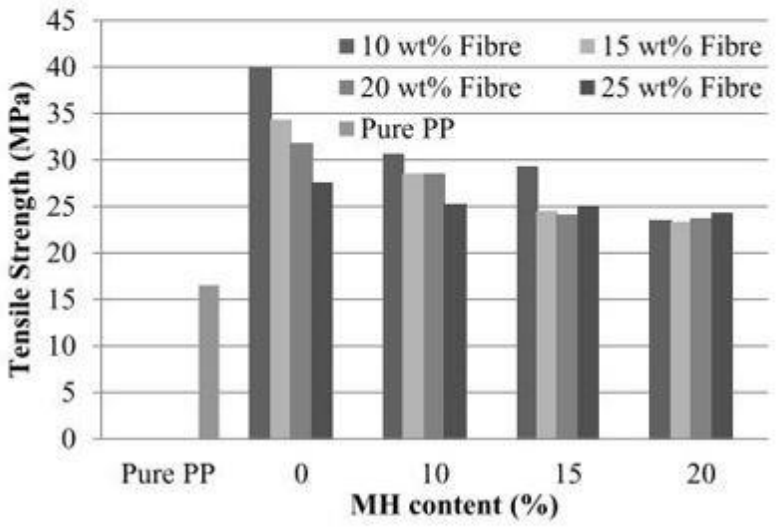

Figure 2.7 Tensile Strength for KF Reinforced PP Composites with MH Fillers.

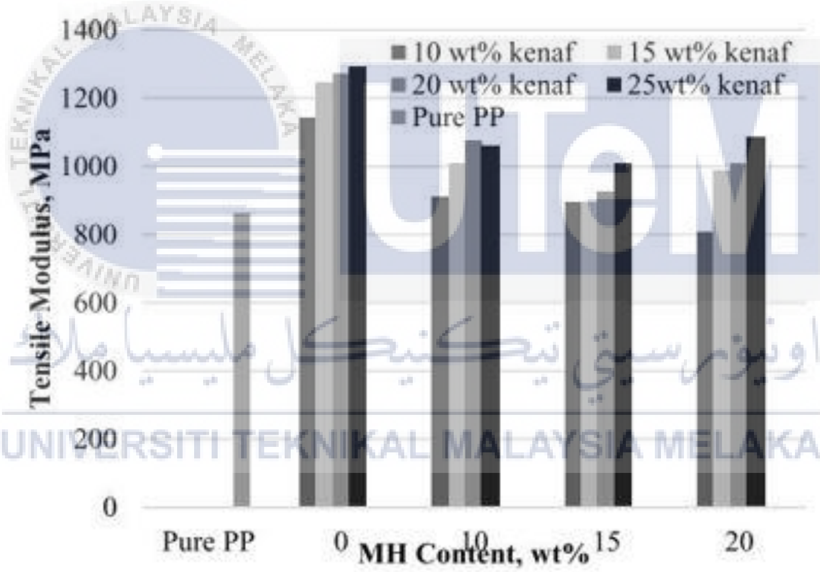

Figure 2.8 Tensile Modulus for KF Reinforced PP Composites with MH Fillers.

For the tensile test, the results showed that composites samples have better tensile strength than pure PP except at certain point such as elongation at break. The composite showed higher tensile strength as the kenaf fiber content increased until certain level. Then, it dropped. Bonding strength between matrix and fiber were weak because the compacting of the composite was poorer as KF content increased. Another reason that caused lower tensile strength was MH flame retardant. Figure 2.9 shows the elongation of KF reinforced PP composites containing MH fillers.

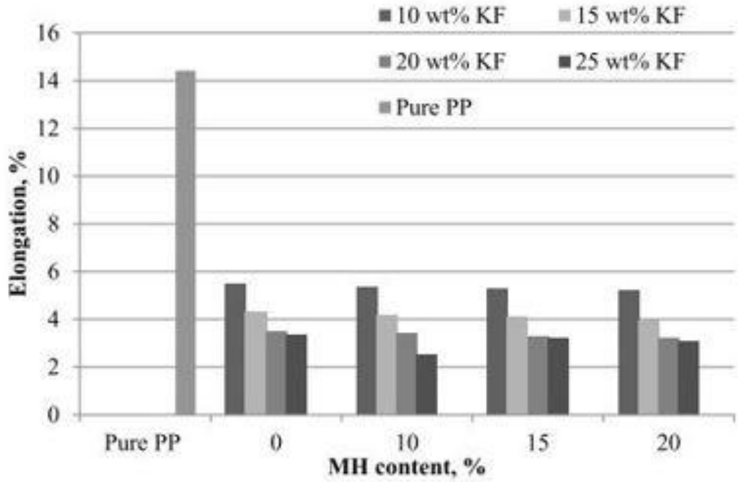

Figure 2.9 Elongation of KF Reinforced PP Composites with MH Fillers.

Addition of kenaf fiber to the composites make it much more rigid and significantly reduced elongation to break. In case of flexural strength, the results were conclude in the Figure 2.10 and Figure 2.11 below.

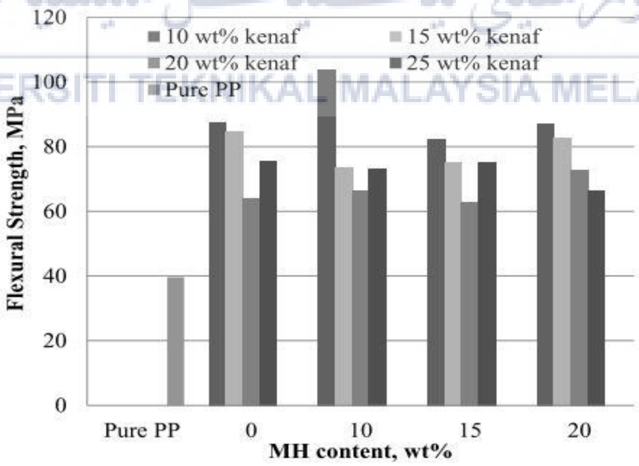

Figure 2.10 Flexural Strength for KF Reinforced PP Composites with MH Fillers.

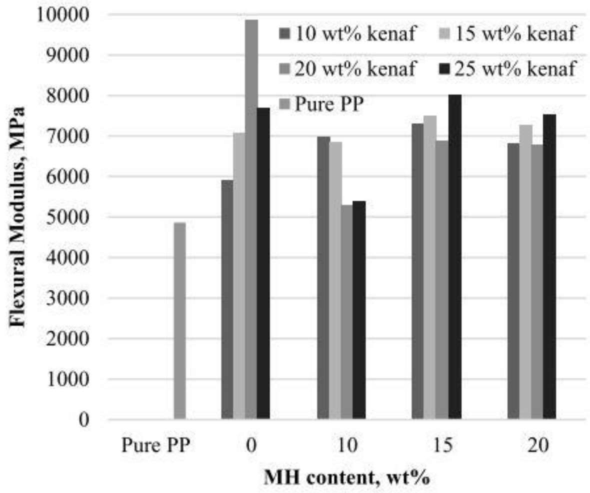

Figure 2.11 Flexural Modulus for KF Reinforced PP Composites with MH Fillers

Generally, the flexural strength of composites increase as the composition of kenaf fiber increased until the kenaf fiber composition achieve 25%wt. The reason of flexural strength going down at this point due to huge number of fiber ends made it easy to crack.

2.6 THERMAL INSULATION

Thermal insulation describing the strength of resisting heat conduction. Thermal insulation is actually oppose to the thermal conduction. Thermal conduction defining transferring of heat from one hot region to cold region, while the thermal insulation defining the resisting of heat transfer from hot region to cold region. Thermal insulation shared some parameter with thermal conduction. The strength of insulating heat is of a substance is actually inversely proportional to strength of conducting heat, thermal conductivity, *k*. As the thermal conductivity of the material higher, the poorer the insulation properties, more heat energy can be resisted.

2.7 YOUNG'S MODULUS

Thomas Young, a physician is the origin of Young's modulus. Basically, Young's Modulus defining the elastic properties of a solid that undergoing compression or tension in single direction. The capability of a material to maintain its length without significant change as it undergoes compression or tension. Young's Modulus also described as the ratio of longitudinal stress to strain (Encyclopaedia Britannica, 2017).

Young's Modulus are usually explained using a simple example such as stretching of metal. A metal bar with a constant cross-sectional area was given force at the both end of the bar. The original length of this bar L_o will achieved a new length of L_n after the forces are applied. As the time moved on, the forces applied would cause the distortion of particle in specimen and decreased the cross-sectional area of metal bar. The quotient of the Force applied to the cross-sectional area is called stress. The strain a ratio that indicating the difference in length of metal bar after stretching, $L_n - L_o$, to the original length, L_o before stretching. Young's Modulus is the ratio of stress to strain. Sample model of stretching metal is shown in figure as below.

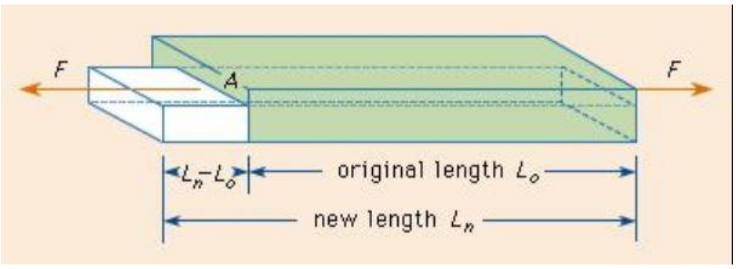

Figure 2.12 Sample of Metal Stretching (Encyclopaedia Britannica, 2017)

In geometry, Modulus of Elasticity has another name, Young's Modulus. It can represented by the slope of the stress-strain diagram within the elastic zone. However, this parameter depend on the material type. Different material can have different slope in stress-strain diagram (Structure and Form Analysis System, 2017).

$$E = \frac{f}{\varepsilon}$$

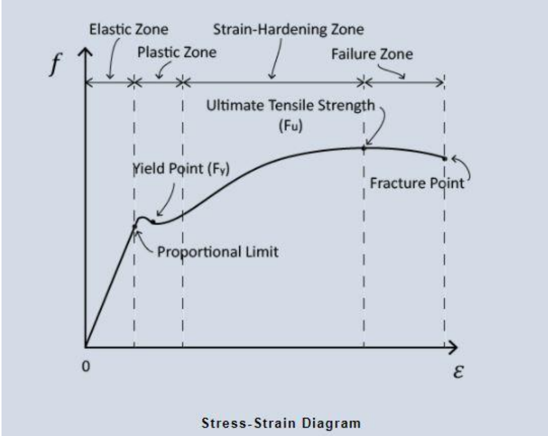

Figure 2.13 Stress-Strain Diagram

The formula of Young's Modulus is summarized as below. Unit for the Young's Modulus, E is Nm^{-2} or Pa (Scool, 2017).

$$E = \frac{\sigma}{\varepsilon} \ldots\ldots\ldots\ldots\ldots \quad (2.2)$$

$$\sigma = \frac{F}{A} \ldots\ldots\ldots\ldots\ldots \quad (2.3)$$

$$\varepsilon = \frac{e}{lo} \ldots\ldots\ldots\ldots\ldots \quad (2.4)$$

$$E = \frac{F\ lo}{A\ e} \ldots\ldots\ldots\ldots\ldots \quad (2.5)$$

2.8 STRESS

Stress is defined as force per unit area as it is the ratio of applied force to cross section area (Scool, 2017). The stress of Young's Modulus is referred to normal stress which is axial stress. It can be either tensile stress or compressive stress depends on the direction of force. The formula of stress is as below.

$$\text{Stress} = \frac{Force}{Cross\text{-}sectional\ Area}$$

$$\sigma = \frac{F}{A}$$

2.9 STRAIN

Strain is defined as extension per unit length (Scool, 2017). It is the ratio of extended length to the original length. The strain has no unit because it is ratio of lengths. The formula of strain is listed as below.

$$\varepsilon = \frac{e}{\ell_0}$$

2.10 FLEXURAL STRENGTH

Flexural strength, with other names, modulus of rupture, bend strength or transverse rupture strength is a mechanical properties of material. It represents the stress in material before it yields (AMETEK, 2017).

Flexural strength is a properties that can be determine from a bending test. This test required to fabricate the specimen to specific dimension according to the standard referred. The specimen is usually fabricated into circular or rectangular shape based on the situation. In flexural test, tensile stress was produced at the convex side of the specimen and compression stress was produced at the concave side. An area of shear stress is created at the middle of specimen due to forces from different support span. Three point flexural test and four point flexural test are common use bending test.

Three point flexural test required of fixing two ends of a specimen and applied one force at middle between the ends. Thus, this flexural strength represents the highest stress the specimen can afford before it fractured. Example layout of three point flexural test is shown as below.

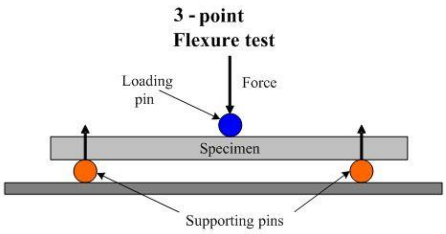

Figure 2.14 Three Point Flexural Test (Slideshare, 2017)

Another type of bending test, four point flexural test has same set up as the three point. The only difference between these two types flexural test is four point test has additional one force apply in between the two ends of specimen. Example layout of four point flexural test is shown as below.

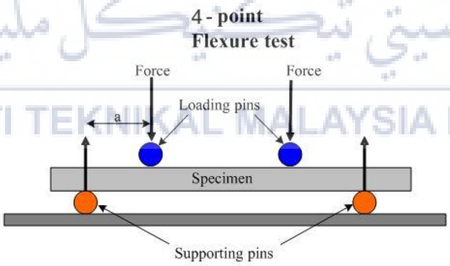

Figure 2.15 Four Point Flexural Test (Slideshare, 2017)

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

In this chapter, the procedures and methods to complete the study were discussed in details. Basically, the procedures are fabrication of specimen, fitting of specimen and testing of specimen. The general procedure was summarized as flow chart below. The detail procedures were discussed from product manufacturing until calculation part and analyse results.

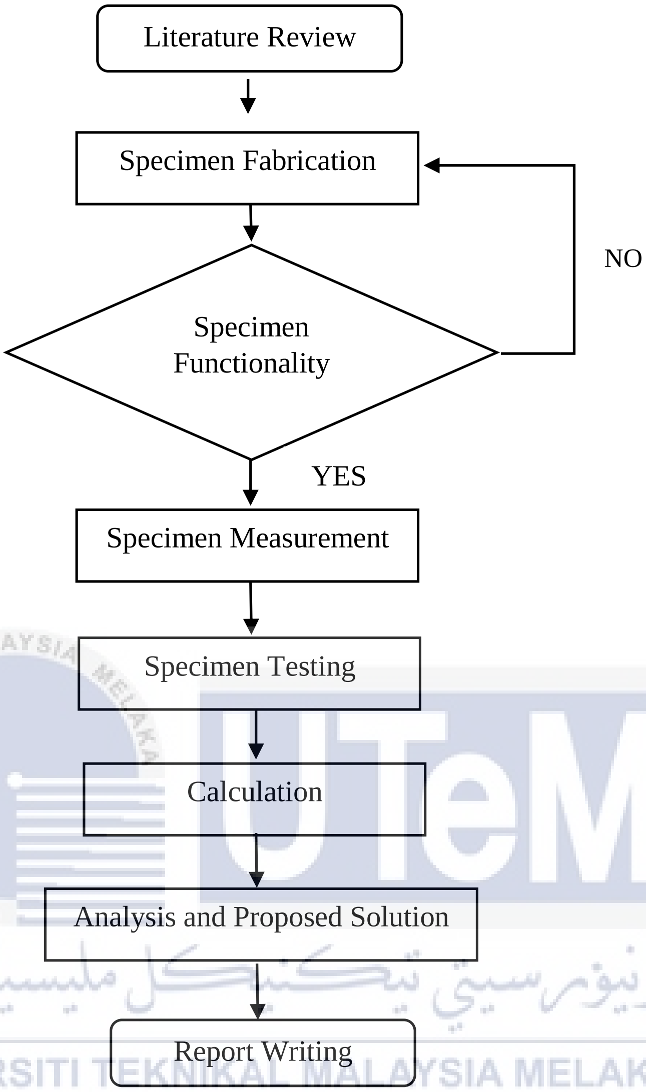

Figure 3.1 Flow Chart of Methodology

3.2 SPECIMEN FABRICATION

In this process, it divided into a few stage listed as below:

- **STAGE 1 : MATERIAL PREPARATION**

  In this stage, the materials used to fabricate the specimen was supplied by Encik Shamsul Bahari, UTeM which is the UTeM lecturer from Faculty of Mechanical Engineering. The origin of this kenaf powder is from Institute Penyelidikan dan Kemajuan Pertanian Malaysia (MARDI). The materials supplied were kenaf powder, which is kenaf in powder form and polypropylene.

Figure 3.2 Kenaf Powder

Figure 3.3 Polypropylene (PP)

- **STAGE 2: INTERNAL MIXING**

In this stage, kenaf powder and polypropylene were mixed in the machine. The internal mixing machine is showed as below.

Figure 3.4 Internal Mixer Machine

First, the weight proportion of kenaf powder and polypropylene in composite was fixed and listed as in table below. The total weight must not exceed 50g.

Table 3.1 Weight Proportion of Kenaf Powder and Polypropylene In Composite

Specimen	Weight Proportion (%)	
	Kenaf Powder	Polypropylene(PP)
1	20	80
2	30	70
3	40	60
4	50	50

As the materials with respective weight were ready, specimen 1 was created first. The polypropylene (PP) was first insert into the internal mixing machine as the binder due to high melting point at 190 ℃. The polypropylene (PP) was heated up for three to four minutes at 190 ℃ to ensure it was fully melted. After that, kenaf powder was inserted and continued to heat up for another four minutes. In the machine, the melted polypropylene (PP) and kenaf powder were supposed to mix together but it was believed not evenly for the mixture. The mixture was cooled down and left at solid lump form.

By using the internal mixer machine, composite of kenaf powder and polypropylene was produced in the solid lump form.

Figure 3.5 Composite Lump

- **STAGE 3: CRUSHING COMPOSITE LUMP TO GRANULE**

As the mixture is not evenly, the composite lump needed to be process again to get evenly composite product. The composite granules were now inserted into the crushing machine to be crushed again to become granule form. The crushing machine is showed as below.

Figure 3.6 Crushing Machine

The composite lump was crushed into composite granule.

Figure 3.7 Composite Granule

- **STAGE 4: HOT PRESSING COMPOSITE GRANULE**

After the composite lump was crushed into granule form, it was sent to hot press. The composite granule was filled into the prepared mould. In this project, basically two molds are used to fabricate the specimen. Somehow, it depends on the testing. This is because each testing will required different dimension of specimen to be tested. For the tensile test and flexural test, the required specimen are very thin so a mold with 200mm long x 200mm width x 3 mm thick was selected.

Figure 3.8 Rectangular Mold

Mass of granule to be inserted into this mold has been calculated.

$$m = \rho V \text{ ………… (3.1)}$$

$$m = 0.91\text{g/cm}^3 \text{ x } (20.0 \text{ x } 20.0 \text{ x } 0.3) \text{ cm}^3$$

$$= 109.2\text{g}$$

Therefore 109.2g of composite granule is poured into this mold and inserted into the hot press machine.

Figure 3.9 Hot Press Machine

The temperature of the machine was pre-set at 190 ℃. As the temperature of the hot press machine achieved, the mold was put on a plate and insert the mold with composite granule. Another side of the mold was closed with another plate. The mold lifted in the machine to contact with upper and lower heating surface. Lifting process stopped as the heating surface touched the mold. This situation is call preheating and left for one to two minutes. Then, the mold was lowered in order to apart from another heating surface to provide space for the trapped air to be escaped from the mold. Re-lifting the mold to contact with another heating surface and continue allowing the hot press machine to apply force to the plate and mold up to 50kg/cm^2. The compression was stopped and left for five to seven minutes for heating. The timer of hot press machine can be set in order to help lower the mold after the heating process. Water pipe was turned on and the covered mold was moved to cooling space for cooling up to five minutes. Specimen was removed from the mold.

Figure 3.10 Rectangular Specimen with 3.0mm Thickness

For heat transfer test, the required mold is different. It would need a bigger rectangular mold. In order to fit with the heat transfer testing method, the dimension of specimen required is 300.0mm x 300.0mm x 6.0mm.

Mass of granule to be inserted into this mold has been calculated.

$$m = \rho V$$

$$m = 0.91 g/cm^3 \times (30 \times 30 \times 0.6)\ cm^3$$

$$= 491.40g$$

This amount of granule was inserted into mold and sent to hot press as method of tensile test and flexural test specimens. The only different thing was heating time. Since this specimen has the thickness of 6.0mm, the heating time was increased for extra five minutes.

Figure 3.11 Rectangular Specimen with 6.0mm Thickness

As the specimens fabricated were in good condition, next step was carry on.

3.3 SPECIMEN MEASUREMENT AND FITTING

In this session, the specimens were being measured to determine the dimension and consistency of thickness. After that, the specimens were fitted to specific dimension to undergo various type of testing.

3.3.1 Heat Transfer Test

In this test, the required dimension for testing was set at 300.0mm length, 300.0mm width and 6.0mm thick, which is same as the mold used during hot press. Thus, there was no any fitting to the specimen.

3.3.2 Tensile Test

In this test, the required dimension for testing is showed in the Figure 3.12 and Table 3.2.

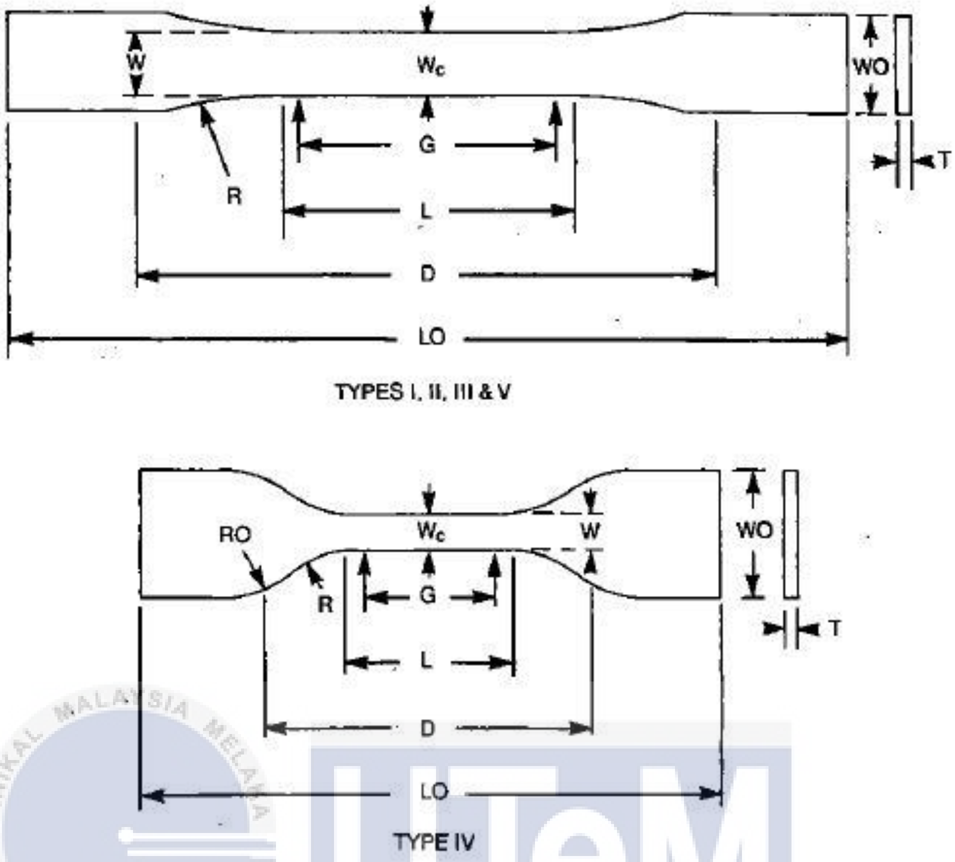

Figure 3.12 Diagram of Tensile Test Specimen Dimension

Table 3.2 Table of Tensile Test Specimen Dimension

Dimensions (see drawings)	7 (0.28) or under		Over 7 to 14 (0.28 to 0.55), incl	4 (0.16) or under		Tolerances
	Type I	Type II	Type III	Type IV[B]	Type V[C,D]	
W—Width of narrow section[E,F]	13 (0.50)	6 (0.25)	19 (0.75)	6 (0.25)	3.18 (0.125)	±0.5 (±0.02)[B,C]
L—Length of narrow section	57 (2.25)	57 (2.25)	57 (2.25)	33 (1.30)	9.53 (0.375)	±0.5 (±0.02)[C]
WO—Width overall, min[G]	19 (0.75)	19 (0.75)	29 (1.13)	19 (0.75)	...	+ 6.4 (+ 0.25)
WO—Width overall, min[G]	...	...	...	...	9.53 (0.375)	+ 3.18 (+ 0.125)
LO—Length overall, min[H]	165 (6.5)	183 (7.2)	246 (9.7)	115 (4.5)	63.5 (2.5)	no max (no max)
G—Gage length[I]	50 (2.00)	50 (2.00)	50 (2.00)	...	7.62 (0.300)	±0.25 (±0.010)[C]
G—Gage length[I]	...	...	...	25 (1.00)	...	±0.13 (±0.005)
D—Distance between grips	115 (4.5)	135 (5.3)	115 (4.5)	65 (2.5)[J]	25.4 (1.0)	±5 (±0.2)
R—Radius of fillet	76 (3.00)	76 (3.00)	76 (3.00)	14 (0.56)	12.7 (0.5)	±1 (±0.04)[C]
RO—Outer radius (Type IV)	...	...	...	25 (1.00)	...	±1 (±0.04)

The reason of this dimension has been used was referring to American Society for Testing and Materials (ASTM). The ASTM D638 is suitable to be referred due to the material and its properties. The sizing of specimen was selected as type I because this specimen is reinforced composite. The specimens fabricated were fitted into set dimension by using sample cutting machine and mitre saw.

Figure 3.13 Sample Cutting Machine

Figure 3.14 Mitre Saw

By referring to type I in ASTM D638, speed of testing was set at 5mm/min and nominal strain rate at start of test was set at 0.1 mm/min. Five samples were tested for each specimen. Cut sample showed dumbbell shape.

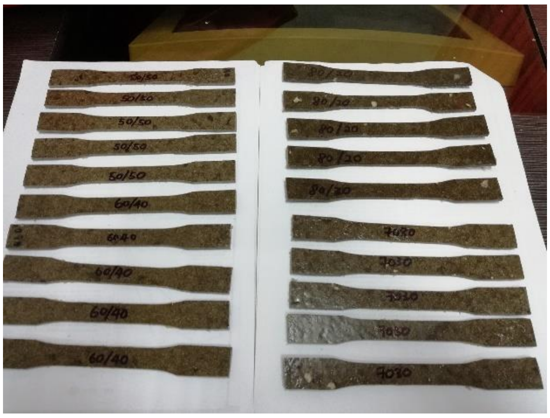

Figure 3.15 Dumbbell Shape Specimen

3.3.3 Flexural Test

In this test, the required dimension for testing is 127mm length by 12.7mm width and thickness of 3.0mm. The reason of this dimension has been used was referring to ASTM D790. By referring to this standard, width and depth of the specimen will be measured. Then, the rate of crosshead motion will be calculated using the following formula.

$$R = \frac{ZL^2}{6d} \qquad (3.2)$$

By applying the value, Z = 0.01 mm/mm/min, L = 48.0mm, d = 3.0mm, and support span to depth ratio of 16. Value of R was determined to be 1.28 mm/min. The specimens were cut into desired dimension by using mitre saw. Five samples were tested for each specimen.

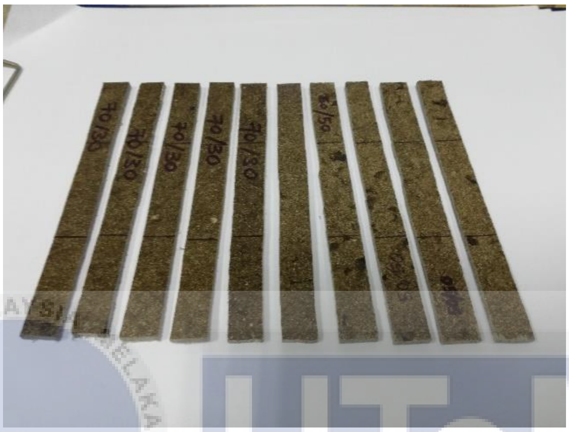

Figure 3.16 Strip Specimen

3.4 SPECIMEN TESTING

3.4.1 Heat Transfer Test

In this test, an infrared lamp and an infrared thermometer was used. Infrared lamp acted as a power heat source while the infrared thermometer is a temperature measurement device. The output power of the infrared lamp is 150W. At the beginning, the infrared lamp was set up in a room with low air movement, to prevent it affect the heating effect. The specimen was set up to be stood perpendicular to the infrared lamp. The distance between infrared lamp and specimen was set at 30.0cm. As the power of infrared lamp turned on, the time started counting. Temperature of the hot surface (face to infrared lamp) and cold surface (opposite face to the infrared lamp) were recorded every 2 minutes until 16 minutes or until the temperature remained constant. Constant temperature on both side of specimen indicate there was no extra heat gain or heat loss. The specimen had achieved constant heat transfer rate, therefore the thermal conductivity of specimen can be determined at this point. The temperature was taken by placed the infrared thermometer at the center of hot surface and center of cold surface. After every 2 minutes, infrared thermometer placed at the centre, button on thermometer was pressed, and temperature showed were recorded. The test was repeated until all composite of different proportion finished testing.

Figure 3.17 Philips Infrared Lamp H3616

Figure 3.18 Infrared Thermometer

3.4.2 Tensile Test

In this test, dumbbell shape specimens were used. Initial, the gage length of the specimens were marked before testing. Then, specimen was gripped and fixed at the machine. Apparatus and setting in computer were set up and the test started. The grip slowly pulled the specimen according to the set speed. The test was continued until the specimen broke. The gage length and total length after the specimen broke was recorded. The tensile strength of specimen was determined in the software and the data was saved. The name of the tensile test machine is INSTRON 8872 Universal Testing Machine. Diagram of the tensile test machine is shown as below.

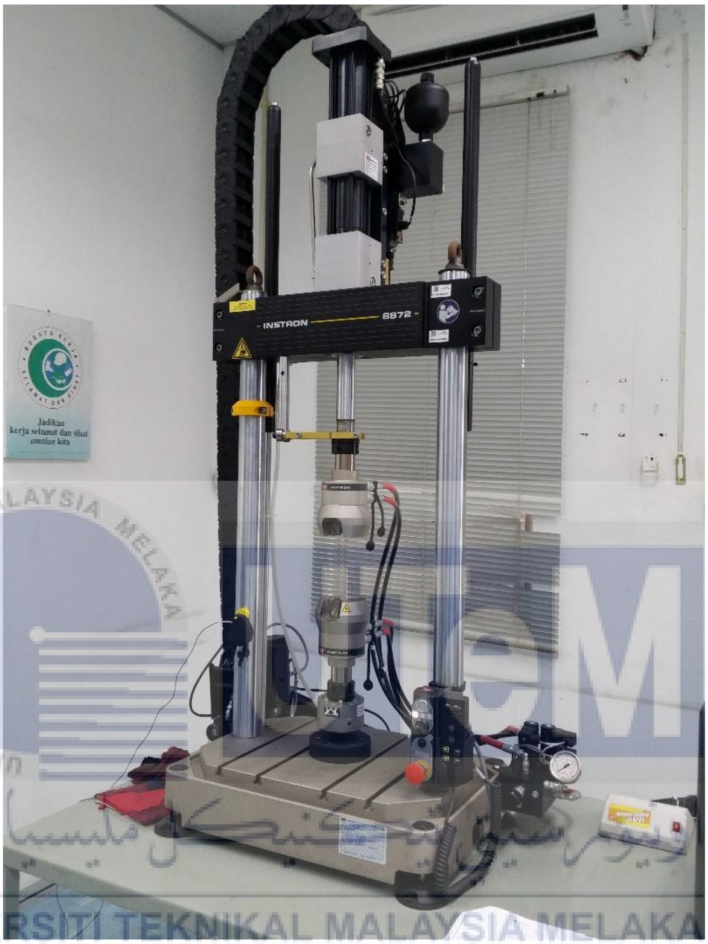

Figure 3.19 INSTRON 8872 Universal Testing Machine

3.4.3 Flexural Test

In this test, rectangular shape specimens were used. Support span was set at 48.0mm while the thickness for specimens was 3.0mm. 127mm length specimen was placed above support with 48.0mm length in the middle placed within the support span. Crosshead motion was set at 1.28mm/min. Position of crosshead was set as it touched the specimen and all the force was balanced to zero. The test started by applying crosshead motion. The crosshead touched the specimen and forced it to bend slowly.

The test was stopped when the expansion side of the specimen started to crack or the stress of specimen showed significant drop in monitoring software. The highest stress before it cracked was recorded in software and the data was saved. The name of the tensile test machine is INSTRON 5585 Universal Testing Machine. Figure of the flexural test machine is shown as below.

Figure 3.20 INSTRON 5585 Universal Testing Machine

3.5 CALCULATION

Calculation needs to be done on data obtained from the test.

- **Heat Transfer Test**

Calculation need to be done due to the thermal conductivity value of specimen doesn't show directly from the data obtained. A few formulae were used to determine the thermal conductivity, *k* of specimens.

$$\frac{Q}{t} = kA\frac{\Delta T}{\Delta X} \qquad (3.3)$$

$$\frac{Q}{t} = P = VI \qquad (3.4)$$

$$k = \frac{VI}{A\frac{\Delta T}{\Delta X}} \qquad (3.5)$$

CHAPTER 4

RESULTS AND DISCUSSION

In this chapter, all the results of testing of specimens are showed and discussed.

4.1 TESTING OF SPECIMEN

4.1.1 TENSILE TEST

Tensile test specimens were fabricated and fitted to dumbbell shape as well. After the specimens were tested by using the INSTRON 8872 Universal Testing Machine, specimens showed the fracture at the middle of the specimens and result was tabulated in computer.

Figure 4.1 Tested Tensile Test Specimen

Table 4.1 Tensile Test Results of Kenaf Composite

Kenaf Composite	20% Kenaf 80% PP	30% Kenaf 70% PP	40% Kenaf 60% PP	50% Kenaf 50% PP
Tensile Stress (MPa)	7.788	7.770	7.062	4.42
Density (g/cm^3)	0.91	0.91	0.91	0.91

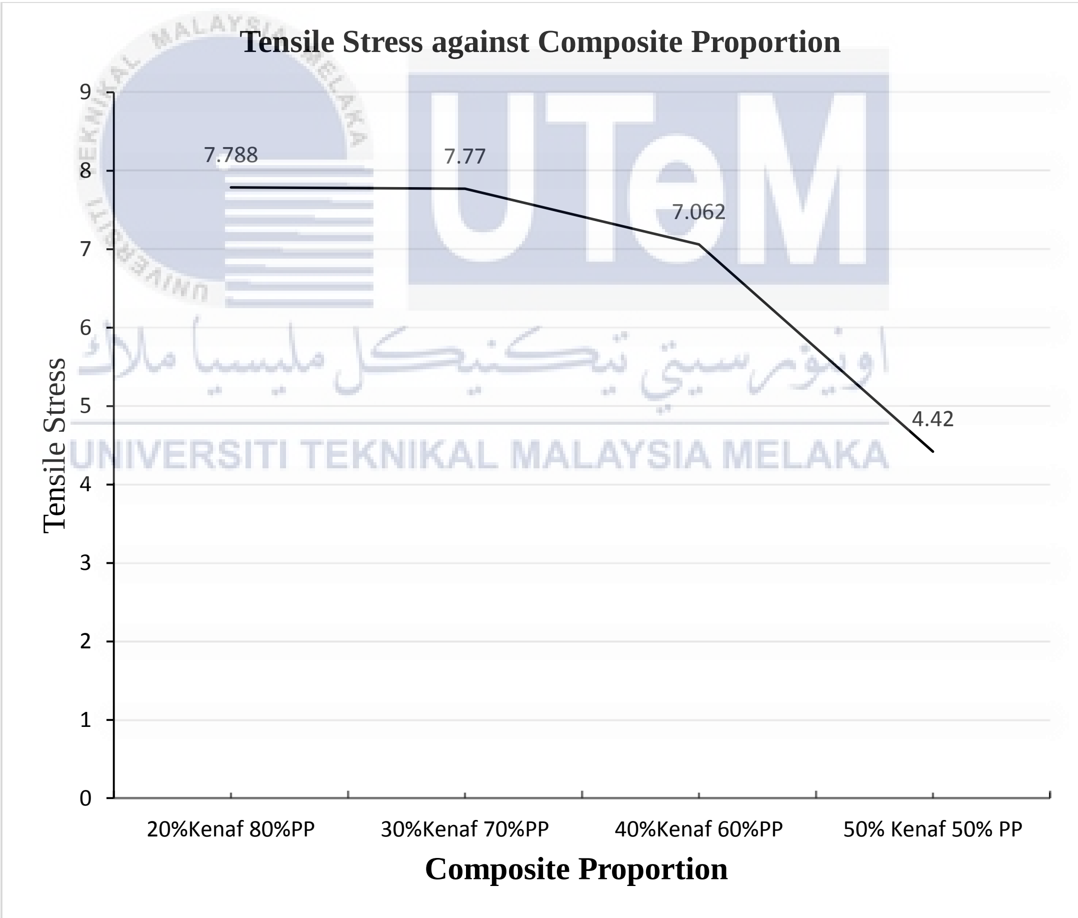

Figure 4.2 Tensile Stress against Composite Proportion

From the Table 4.1 and Figure 4.2, it showed that the tensile test results of kenaf powder and polypropylene composite. The results showed the data of tensile strength for different proportion composite. The tensile strength for 80% PP 20% kenaf composite is 7.788 MPa, 70% PP 30% kenaf is 7.77MPa, 60% PP 40% kenaf is 7.062 MPa and 50% PP 50% kenaf is 4.420MPa. By referring to the trend line from the graph, the tensile strength of the composite has slightly dropped as the kenaf proportion increase up to 40%, and drastically dropped when kenaf proportion increase up to 50%. The tensile strength of this kenaf composite relies on the proportion of kenaf. The tensile strength of kenaf composite was consistent as the kenaf proportion in composite increase up to 70%. As more kenaf powder was mixed in the composite, the tensile strength of the composite dropped. This may due to the excess short fiber end in the composite, lead to particle distortion in composite. Thus, the tensile strength started to drop after kenaf proportion in composite more than 70%, and show drastically drop at 50%.

The results for this tensile stress test, is lower than the expected results assumed from literature review. The machine for this tensile test was suspected not suitable for the composite as well. The universal testing machine used for tensile test was suspected to be suitable for metal type with high strength. Therefore, when used the kenaf composite with low tensile strength to do test, the results was lower than expected. However, the relationship between the kenaf proportion in composite and its strength was able to be proved as well.

The results was then compared to the study done by the previous researchers. A comparison was made to the study on mechanical and thermal properties of kenaf fiber (KF) reinforced polypropylene (PP) and magnesium hydroxide (MH) composites e this situation to be happened. The fiber length used in the previous study and in this experiment was totally different. As the fiber length is different, much variation of the results may happen. Furthermore, in previous study, researchers would like to add in extra chemical to improve the stability and properties of material. For example, the chemical added in study mentioned is Magnesium Hydroxide fillers. This chemical was used to act as load bearing components so the results may show enhanced results. Another difference in results obtained, may due to difference in the density of composite. For the composite in this experiment, the density is set at 0.91g/cm^3. While for the research in the previous, the density set was 0.93g/cm^3. The difference in the density may cause huge impact to the properties of the composite.

In the relationship between kenaf proportion and composite strength, experiment done obtained the same trend line as the previous study. From the previous study, researchers obtained the results of increasing kenaf proportion may decrease the tensile strength of composite as well.

Next, the results from experiment was compared to the research on the effect of kenaf fiber as reinforcement on tensile strength, flexural strength and impact toughness (Suharty et al., 2016). From this previous research, tensile strength of kenaf fiber obtained was around 32.32MPa, which is higher than results from experiment. A direct comparison to the results was forbidden due to different fiber length used in research. In the research of the Suharty, the kenaf fiber used was cut to 5.0mm in size, while for this experiment, the kenaf fiber used was kenaf powder with the size of 120μm. In term of this difference in kenaf size, the results may vary a bit from the expected results.

As kenaf content increased in composite, the composite had poorer compacting of the composite and caused weaker bonding strength between the matrix and the fiber. Hence, a trend line of going down of tensile strength as the kenaf proportion increased. Furthermore, high fiber contents in the composites may result in insufficient fiber wetting, thus impacting the load transfer mechanism in the composite, leaded to lower strength properties.

4.1.2 FLEXURAL TEST

Flexural test specimens were fabricated and fitted to rectangular strip shape as well. After the specimens were tested by using the INSTRON 5585 Universal Testing Machine, specimens showed the fracture at the middle of the lower face of specimens. The results were tabulated in computer.

Figure 4.3 Tested Flexural Test Specimens

Table 4.2 Flexural Test Results of Kenaf Composite

Kenaf Composite	20% Kenaf 80% PP	30% Kenaf 70% PP	40% Kenaf 60% PP	50% Kenaf 50% PP
Flexural Stress (MPa)	31.793	31.229	27.715	17.202
Density (g/cm^3)	0.91	0.91	0.91	0.91

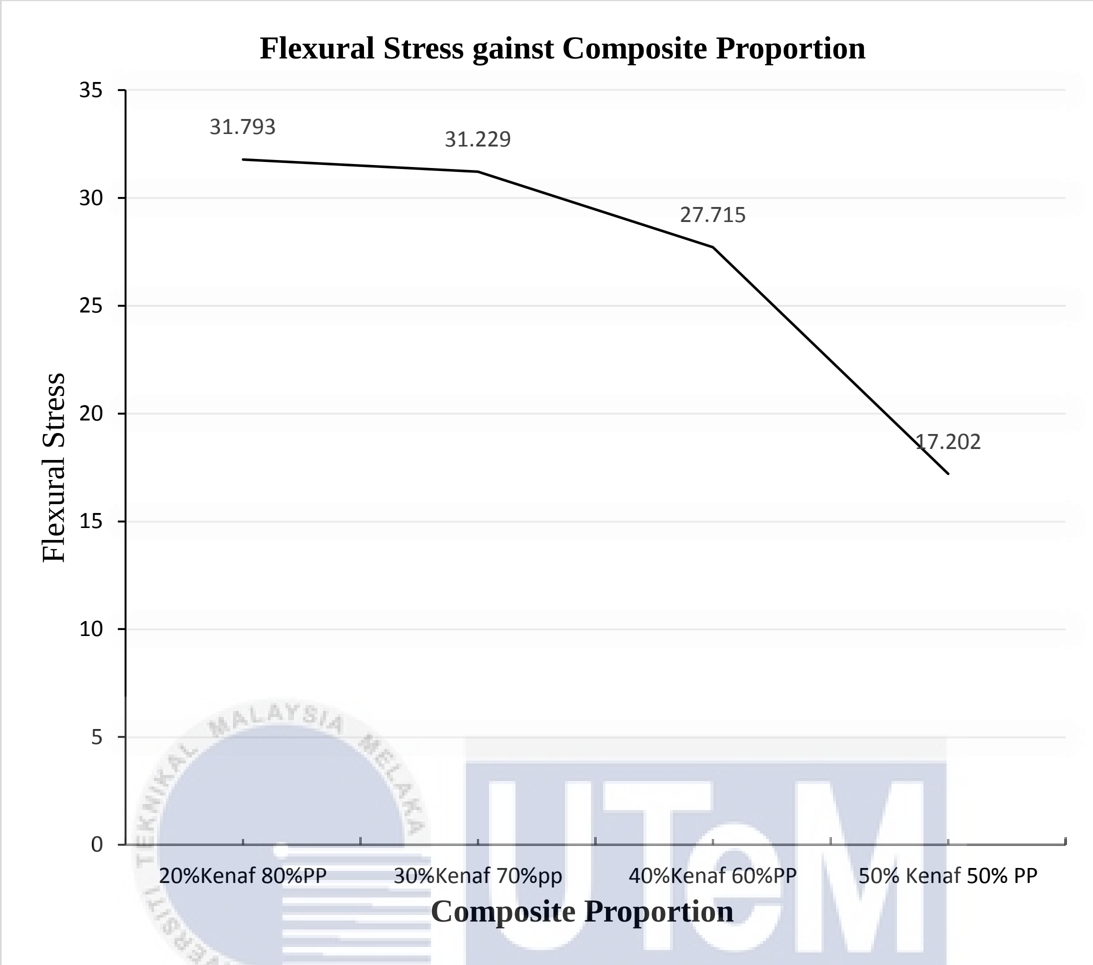

Figure 4.4 Flexural Stress against Composite Proportion

From the Table 4.2 and Figure 4.4, it showed the flexural test results of kenaf powder and polypropylene composite. The flexural strength of composites were clearly stated in Table 4.2 and plotted in Figure 4.11. The results showed the data of flexural strength for different proportion composite. The flexural strength for 80% PP 20% kenaf composite is 31.793 MPa, 70% PP 30% kenaf is 31.229 MPa, 60% PP 40% kenaf is 27.715 MPa and 50% PP 50% kenaf is 17.202 MPa. By referring to the trend line from the graph, the flexural strength of the composite has slightly dropped as the kenaf proportion increase up to 40%, and drastically dropped when kenaf proportion increase up to 50%. The flexural strength of this kenaf composite depends on the proportion of kenaf. The flexural strength of kenaf composite was consistent as the kenaf proportion in composite increase up to 70%. As more kenaf powder was mixed in the composite, the flexural strength of the composite dropped.

Overall results obtained from the experiments showed the usage of the natural fiber kenaf in composite had increase the flexural strength. However, the enhanced flexural strength varies for different proportion of kenaf content. No significant change in the flexural strength when kenaf content in composite less than 30%. This indicate the composite is stable in term of flexural strength when kenaf content is less than 30%. Drop of the flexural strength of composite when kenaf content increase may due to excessive short end of kenaf fiber. Since the kenaf powder used was in size of 120μm, too much short end of kenaf fiber caused the distortion of the material, thus the flexural strength decreased.

Results obtained from experiment was used to compare with previous research as well. Based on the research flexural and compressive properties of hybrid kenaf or silica nanoparticle (Bajuri et al., 2016), the flexural strength of composite was 43.8 MPa when the composite made of kenaf fiber, epoxy resin and 2 vol% hydrophobic silica nanoparticles. The flexural strength dropped as the silica nanoparticle's loading increased. While for current experiment, kenaf composites' flexural strength dropped as the kenaf content increased. Both of the previous research and current experiment showed the kenaf composite has high flexural stress over 30.0 MPa. The difference between the results obtained from experiment and previous research maybe because of the add-on chemicals. Those chemical used in previous research was able to enhance the matrix of the composite and thus improved the mechanical properties of composite.

Another comparison was made to the study on mechanical and thermal properties of kenaf fiber (KF) reinforced polypropylene (PP) and magnesium hydroxide (MH) composites (Lee et al., 2017). The results in this previous study showed the flexural strength of 48.0 MPa when kenaf composite had 20% kenaf content, which is 50% higher than the experiments results. Difference in these results may due to two reasons. First, the kenaf fiber size used. In previous study, the kenaf fiber size is 5.0mm in length, while for this experiment, kenaf powder of 120µm was used. In term of properties inserted fiber, definitely the properties are different. Second, the difference in density of composite. The density in this experiment was set at 0.91g/cm^3 while in previous research, the density was 0.93g/cm^3. The difference may cause huge impact to properties of composite as the tension of particle in composite was different.

4.1.3 HEAT TRANSFER TEST

Table 4.3 Temperature of Hot and Cold Surface for Different Proportion Kenaf Composite against time

Time (Minute)	Kenaf Composite Proportion							
	20% Kenaf 80% PP		30% Kenaf 70% PP		40% Kenaf 60% PP		50% Kenaf 50% PP	
	Hot Surface Temperature (℃)	Cold Surface Temperature (℃)	Hot Surface Temperature (℃)	Cold Surface Temperature (℃)	Hot Surface Temperature (℃)	Cold Surface Temperature (℃)	Hot Surface Temperature (℃)	Cold Surface Temperature (℃)
0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
2	59.0	46.0	54.0	44.0	56.0	41.0	55.0	40.0
4	67.0	52.0	66.0	51.0	70.0	54.0	70.0	52.0
6	74.0	59.0	72.0	60.0	71.0	63.0	78.0	58.0
8	75.0	61.0	77.0	64.0	81.0	66.0	83.0	66.0
10	76.0	64.0	78.0	64.0	86.0	68.0	89.0	70.0
12	76.0	64.0	78.0	64.0	90.0	74.0	91.0	73.0
14	76.0	64.0	78.0	64.0	90.0	74.0	94.0	76.0
16	76.0	64.0	78.0	64.0	90.0	74.0	94.0	76.0

Table 4.3 listed the detail results obtained from heat transfer test. For each two minutes, the temperature for hot and cold surface were determined by using the infrared thermometer. The temperature was taken until it showed constant temperature among both side of the specimen. All the temperature were recorded.

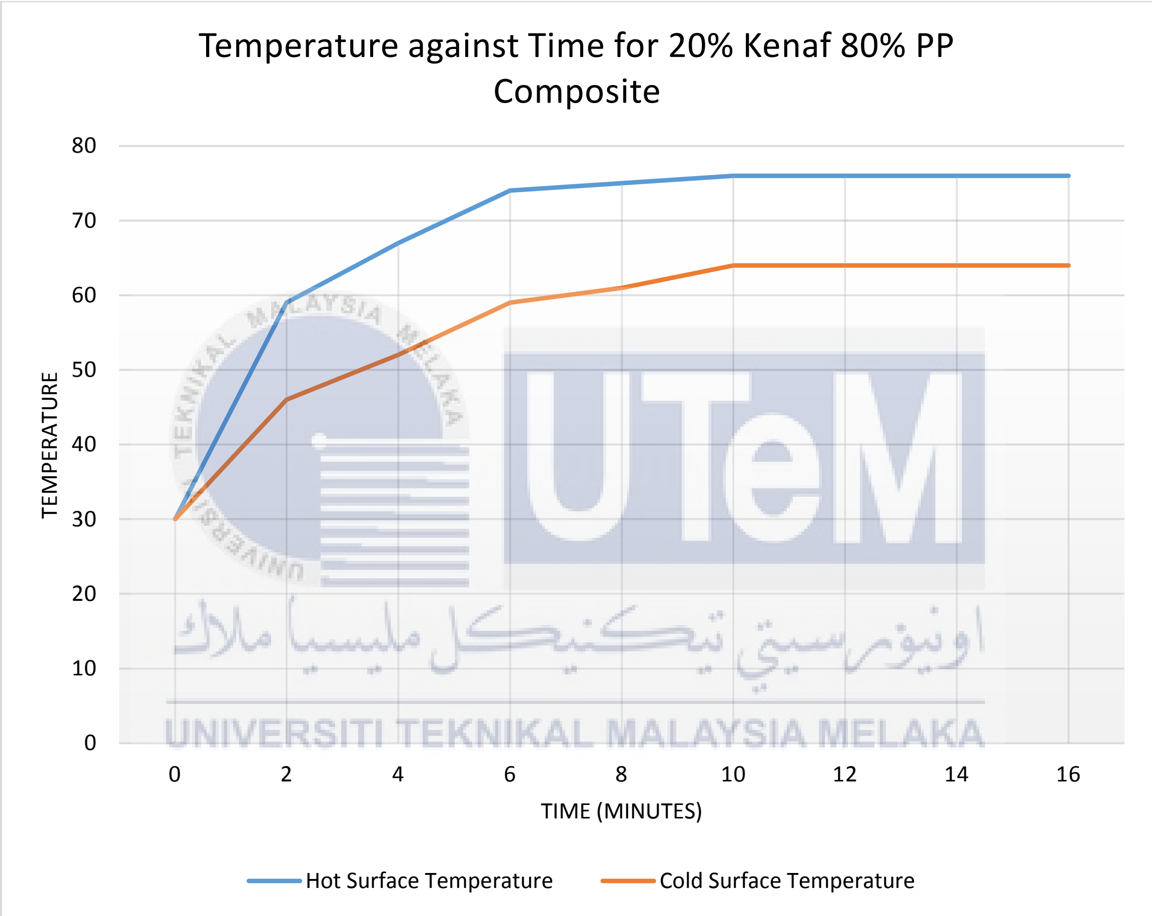

Figure 4.5 Graph of Temperature against Time for 20% Kenaf 80% PP Composite

Figure 4.5 showed the variations of temperature for hot surface and cold surface when supplying heat for 20% Kenaf 80% PP Composite. The temperature need to be constant before we can use it to calculate the thermal conductivity. From the graph, it is clearly showed that the temperatures maintained after 10minutes. Thus, the temperatures after 10minutes were used, which are 76.0 ℃ at hot surface and 64.0 ℃ at cold surface. The thermal conductivity value for this proportion composite was calculated by using formulae and determine to be 7.211 W/m•K.

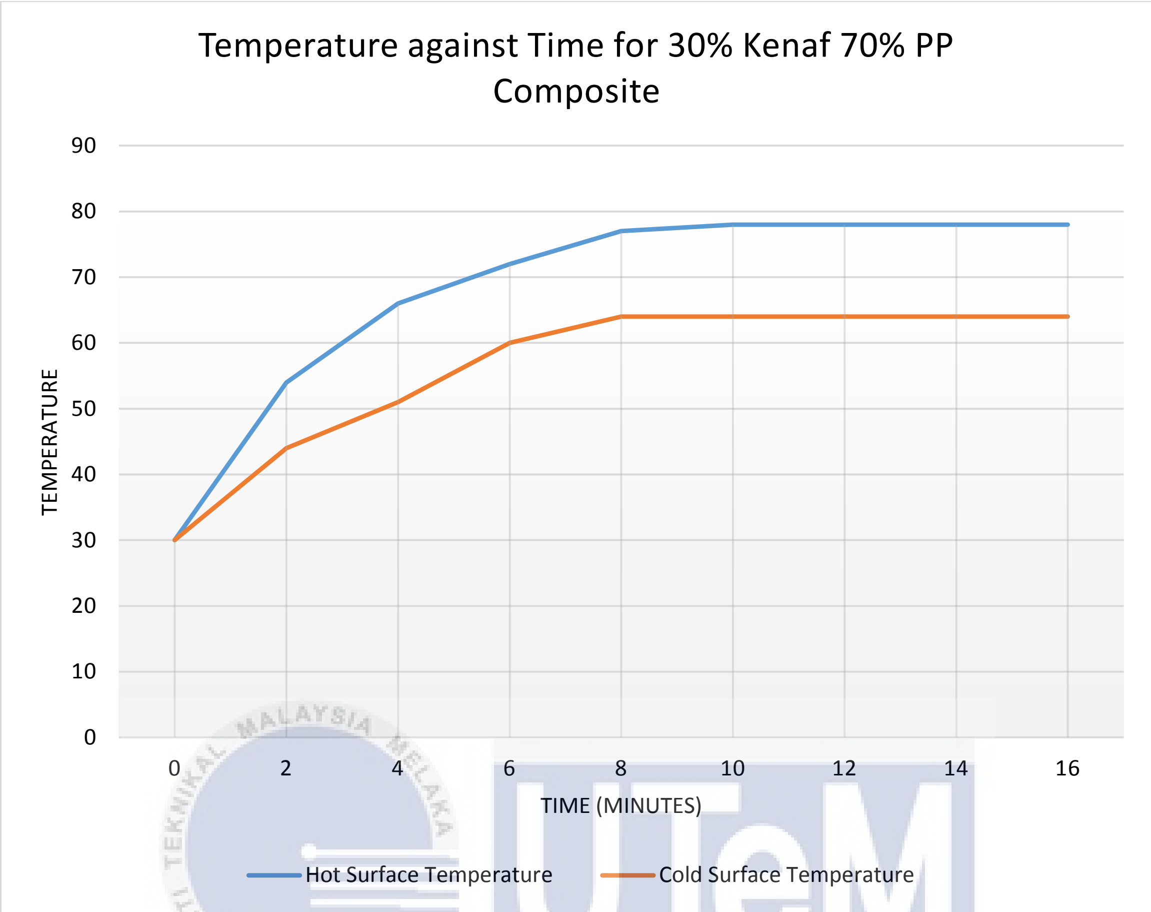

Figure 4.6 Graph of Temperature against Time for 30% Kenaf 70% PP Composite

Figure 4.6 showed the variations of temperature for hot surface and cold surface when supplying heat for 30% Kenaf 70% PP Composite. The temperature need to be constant before we can use it to calculate the thermal conductivity. From the graph, it is clearly showed that the temperatures maintained after 10minutes. Thus, the temperatures after 10minutes were used, which are 78.0 ℃ at hot surface and 64.0 ℃ at cold surface. The thermal conductivity value for this proportion composite was calculated by using formulae and determine to be 6.181 W/m•K.

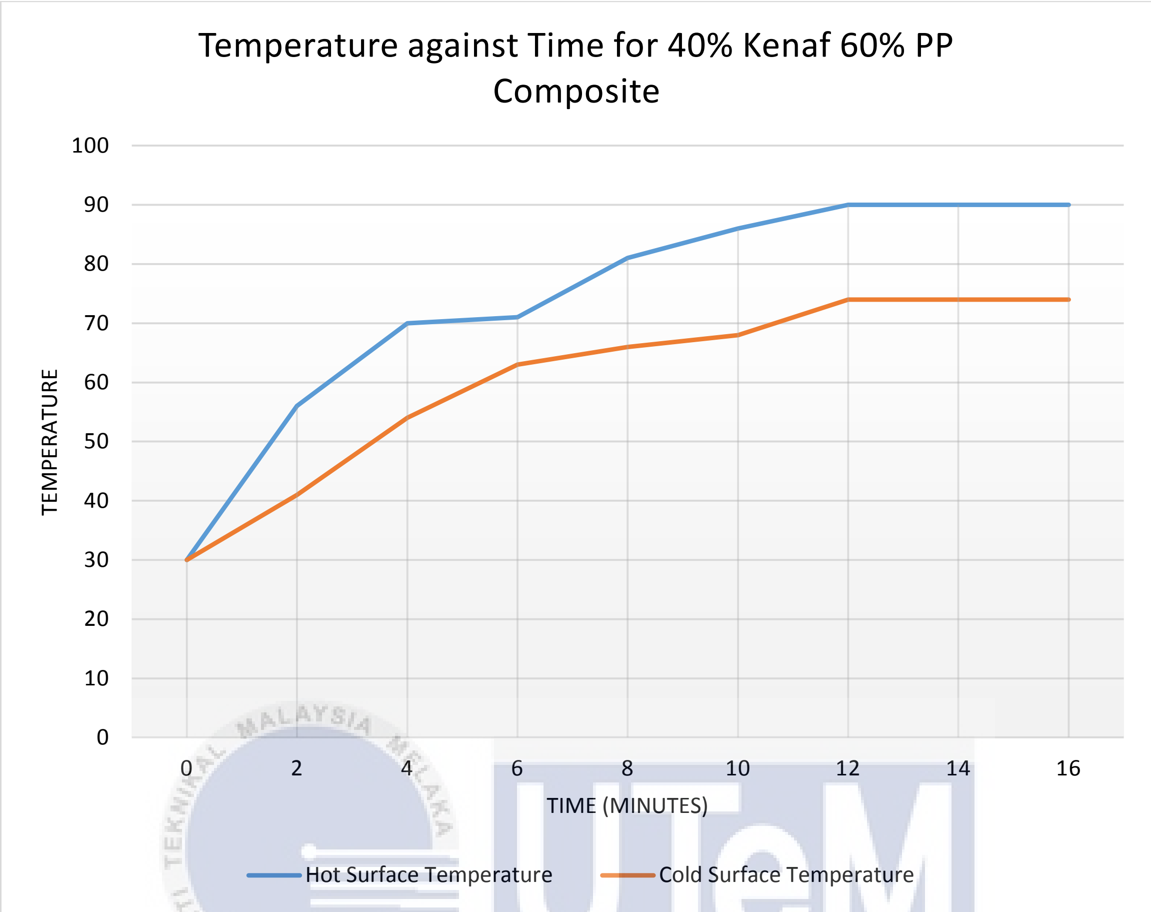

Figure 4.7 Graph of Temperature against Time for 40% Kenaf 60% PP Composite

Figure 4.7 showed the variations of temperature for hot surface and cold surface when supplying heat for 40% Kenaf 60% PP Composite. The temperature need to be constant before we can use it to calculate the thermal conductivity. From the graph, it is clearly showed that the temperatures maintained after 12minutes. Thus, the temperatures after 10minutes were used, which are 90.0 ℃ at hot surface and 74.0 ℃ at cold surface. The thermal conductivity value for this proportion composite was calculated by using formulae and determine to be 5.409 W/m•K.

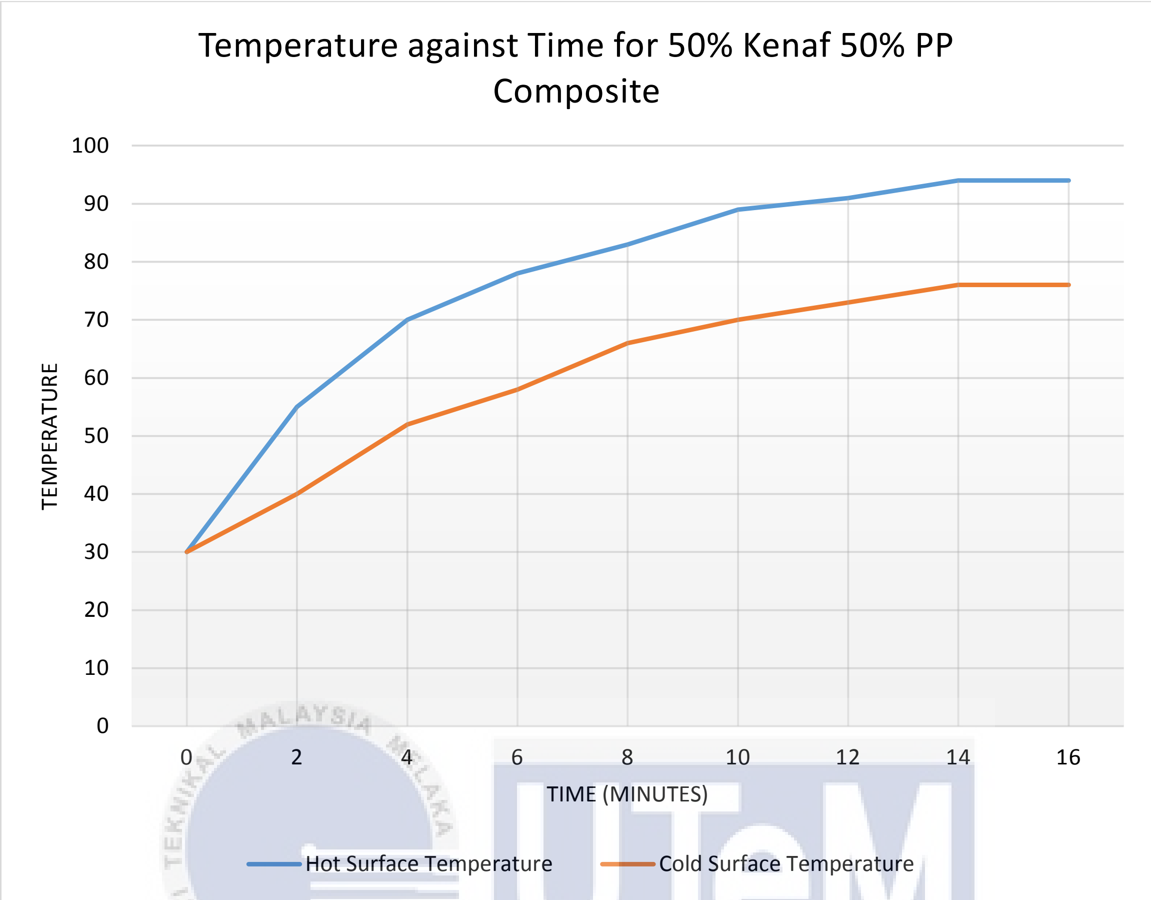

Figure 4.8 Graph of Temperature against Time for 50% Kenaf 50% PP Composite

Figure 4.8 showed the variations of temperature for hot surface and cold surface when supplying heat for 50% Kenaf 50% PP Composite. The temperature need to be constant before we can use it to calculate the thermal conductivity. From the graph, it is clearly showed that the temperatures maintained after 14minutes. Thus, the temperatures after 10minutes were used, which are 94.0 ℃ at hot surface and 76.0 ℃ at cold surface. The thermal conductivity value for this proportion composite was calculated by using formulae and determine to be 4.808 W/m•K.

Table 4.4 Thermal Conductivity, *k* for Different Composite Proportion

	Composite Proportion			
	20% Kenaf 80% PP	30% Kenaf 70% PP	40% Kenaf 60% PP	50% Kenaf 50% PP
Thermal Conductivity, *k* (W/m•K)	7.211	6.181	5.409	4.808

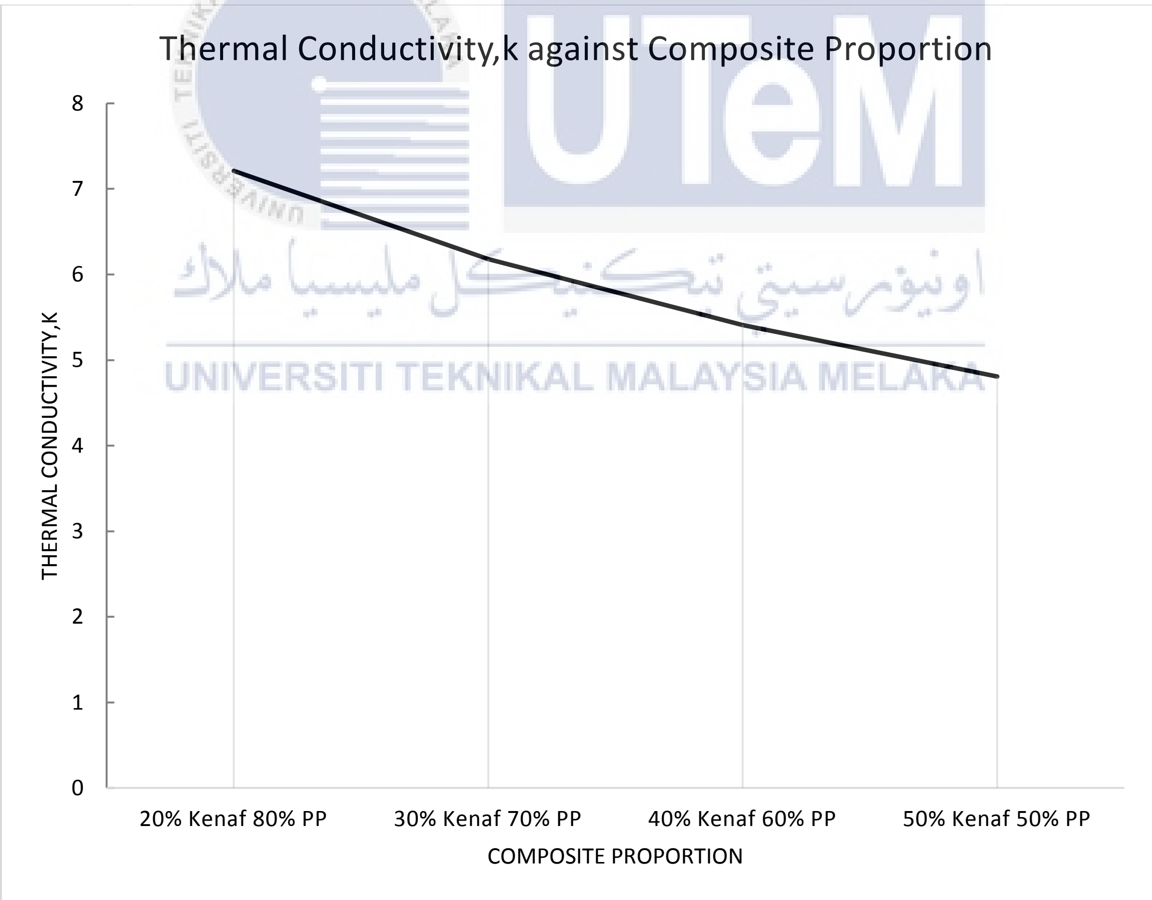

Figure 4.9 Thermal Conductivity, *k* against Composite Proportion

After the thermal conductivity of all specimen were calculated, it were tabulated at Table 4.4 and plotted at Figure 4.9. From these results, it was clear to prove that the thermal conductivity of composite was affected by its composite proportion. This may due to the kenaf content were different for each composite proportion. The thermal conductivity obtained for 20% Kenaf 80% PP is 7.211 W/m•K, for 30% Kenaf 70% PP is 6.181 W/m•K, for 40% Kenaf 60% PP is 5.409 W/m•K and lastly for 50% Kenaf 50% PP is 4.808 W/m•K.

From this results, the composite with lower kenaf fiber content have higher thermal conductivity value, and composite with higher kenaf fiber content have lower thermal conductivity value. In the other way of presenting the results, the composite with lower kenaf fiber content have low thermal insulation properties, and composite with higher kenaf fiber content have high thermal insulation properties. This results from experiment totally achieved the assumption of natural fibre content increase thermal insulation properties. The higher the content of kenaf fiber in the composite, the lower the thermal conductivity, higher the thermal insulation properties and insulating more heat.

This results was compared to the previous study by other researcher. First, thermal insulation properties of kenaf and cotton nonwoven composites (Anuary et al., 2004). For this previous research, the researcher used kenaf and cotton to produce non-woven composite. In term of thermal conductivity, the researchers managed to produce the kenaf composite of 0.39 W/m•K. While for this experiment, the lowest thermal conductivity obtained was 4.808 W/m•K, which is much higher than previous research. This may due to previous research did the experiment with referring to standard ASTM C518, thermal conductivity meter. For this experiment, no specific thermal conductivity instrument was used and not referring to any MS ISO or ASTM standards. Thus, the results may have difference from the expected.

Furthermore, there is a weakness of using the infrared lamp. The infrared lamp lost partially heat energy to surrounding due to radiation. Although the infrared lamp probably consume 150W power, but the output heat energy may not fully projected to the specimen which was located at 30.0cm far. The heat energy started to lost to surrounding, thus the data obtained may have some kind of error.

Next, the infrared thermometer is a very sensitive device. This device hasn't been calibrate before used to take measurement. Thus, there is possibility of error. The temperature at hot surface was hard to determine as well, due to the infrared thermometer needed to be placed perpendicular to the hot surface. In this case, somehow the infrared thermometer already blocked the path of infrared light transfer from infrared lamp to specimen.

However, this experiment proved the insertion of natural fiber kenaf into plastic, would decrease the thermal conductivity of composite which is same with the previous research. As the thermal conductivity decreased, the thermal insulation properties increased and this fact has been proved.

Kenaf fiber content directly affect the thermal insulation properties of the composite. The thermal insulation properties increased as the kenaf fiber content increased.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

Kenaf is a natural fiber which has wide usage. It is a very suitable material to mix with thermoplastic to fabricate an enhanced properties composite. Use of kenaf fiber efficiently improve the thermal insulation properties depends on the content of fiber. The objectives in this project are achieved. For heat transfer test, the thermal conductivity inversely proportional to the kenaf content. Composite with more kenaf content has better thermal conductivity. For tensile test and flexural test, the 20%Kenaf 80%PP and 30%Kenaf 70%PP composites displayed almost similar properties as their tensile strength and flexural strength are consistent. This research results are compared to previous study and achieved very high accuracy. In overall, kenaf composite with 30% kenaf and 70% polypropylene content is conclude as the most suitable thermal insulation material for construction or industry's use. This proportion composite achieved highest average value in term of material properties among all the tested specimen.

5.2 RECOMMENDATIONS

There are a lot of recommendations at the end of this research. First, replace the materials used in this project. For example, the kenaf can be replace by sisal, ramie, jute, hemp, flax, cotton, coir or abaca. These are the natural plant fiber which can be easily obtain and show high similarity of properties to kenaf. While for polypropylene can be replace by polyethylene. These are materials which possible to replace the kenaf in term of fabricating a thermal insulation material.

The heat transfer test in this project didn't follow any standard during the fitting and testing of specimen. In future research which related, it is recommended that a standard should be complied to obtain a higher accuracy and valid results.

Instruments at UTeM are recommended to be calibrated and maintenance before open for students to use. Failure of instruments wasting the time of students and affecting their research progress.

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APPENDICES

APPENDIX A

DOCUMENT TO BE REFERRED

- ASTM Standard (American Society for Testing and Materials)
  - ASTM D638 (Standard Test Method for Tensile Properties of Plastics)
  - ASTM D790 (Standard Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials)

JOURNAL SOURCE TO BE REFERRED

- Sciencedirect

APPENDIX B

PHOTO OF RESEARCH

Figure: Particle Size Analyser

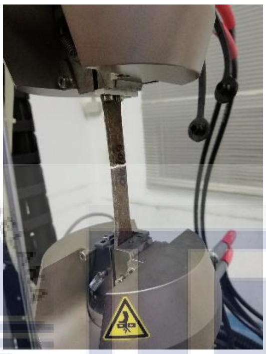


Figure: Fracture of Tensile Test Specimen

Figure: Set up of Flexural Test

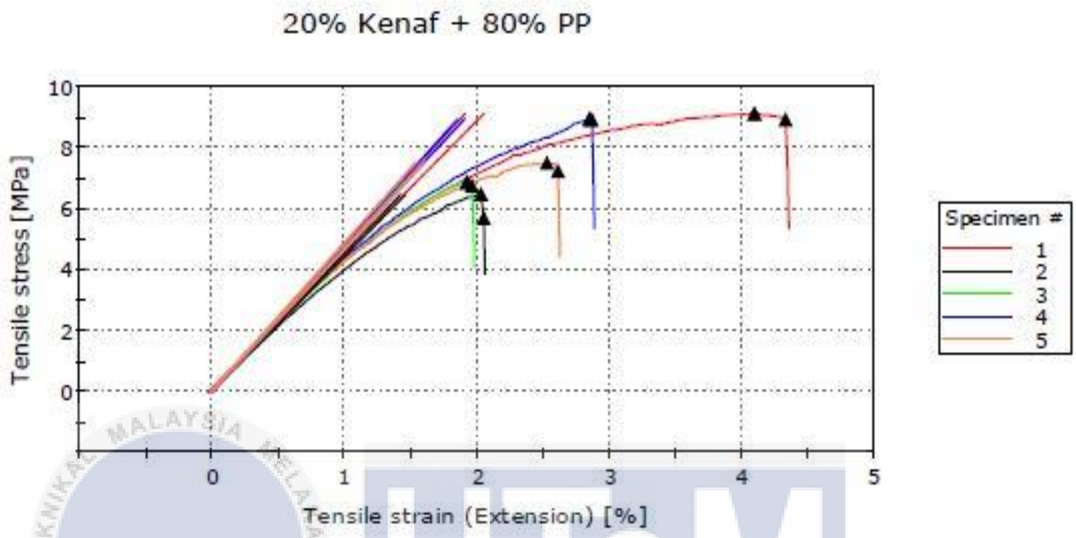
Figure: Set up of Heat Transfer Test

APPENDIX C

DETAIL DATA FOR RESULTS

- **TENSILE TEST**

Tensile Test for KENAF_PP

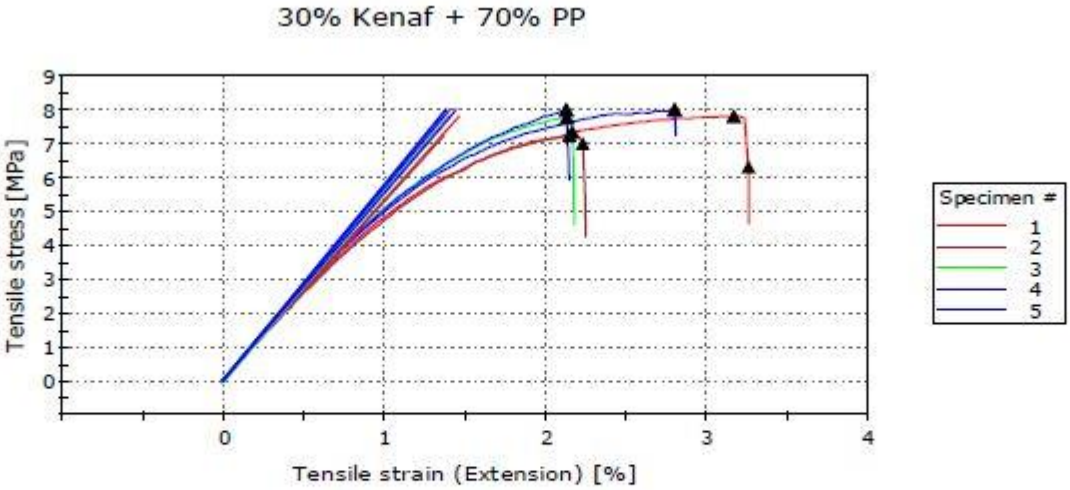


	Maximum Load [N]	Tensile stress at Maximum Load [MPa]	Load at Yield (Zero slope) [N]
1	355.41	9.11	355.41
2	252.69	6.48	252.69
3	268.61	6.89	268.61
4	349.06	8.95	349.06
5	292.96	7.51	-----

	Tensile stress at Yield (Zero slope) [MPa]	Load at Break (Standard) [N]	Tensile stress at Break (Standard) [MPa]
1	9.11	348.30	8.93
2	6.48	222.75	5.71
3	6.89	264.39	6.78
4	8.95	348.54	8.94
5	-----	282.71	7.25

	Modulus (Automatic Young's) [MPa]	Modulus (Automatic) [MPa]
1	474.44	437.78
2	454.51	441.67
3	475.28	466.75
4	480.80	466.84
5	487.21	464.53

Tensile Test for KENAF_PP

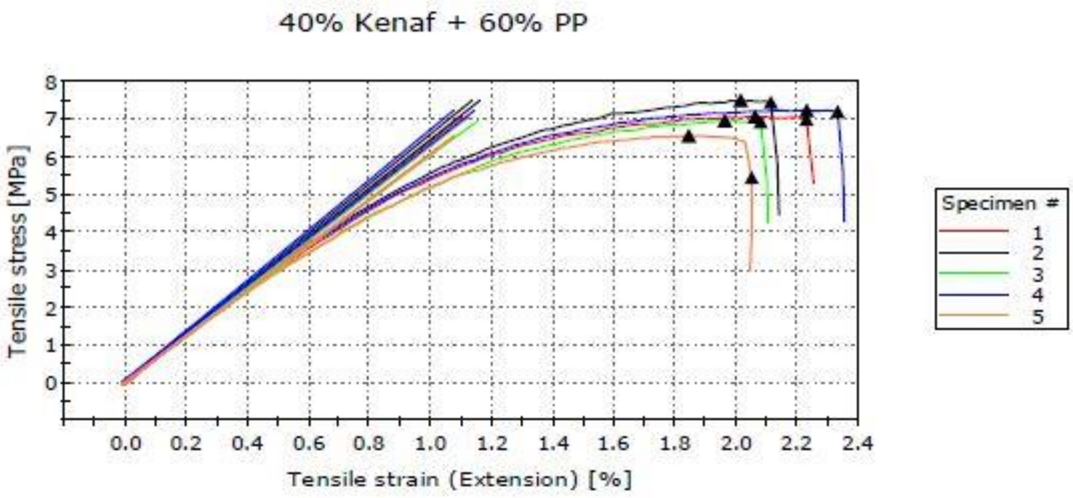


	Maximum Load [N]	Tensile stress at Maximum Load [MPa]	Load at Yield (Zero slope) [N]
1	304.91	7.82	304.91
2	282.59	7.25	282.59
3	303.01	7.77	303.01
4	312.22	8.01	312.22
5	312.14	8.00	312.14

	Tensile stress at Yield (Zero slope) [MPa]	Load at Break (Standard) [N]	Tensile stress at Break (Standard) [MPa]
1	7.82	246.77	6.33
2	7.25	273.58	7.01
3	7.77	287.11	7.36
4	8.01	312.22	8.01
5	8.00	312.14	8.00

	Modulus (Automatic Young's) [MPa]	Modulus (Automatic) [MPa]
1	555.30	528.87
2	552.99	525.79
3	571.64	548.72
4	575.62	548.94
5	577.85	565.82

Tensile Test for KENAF_PP



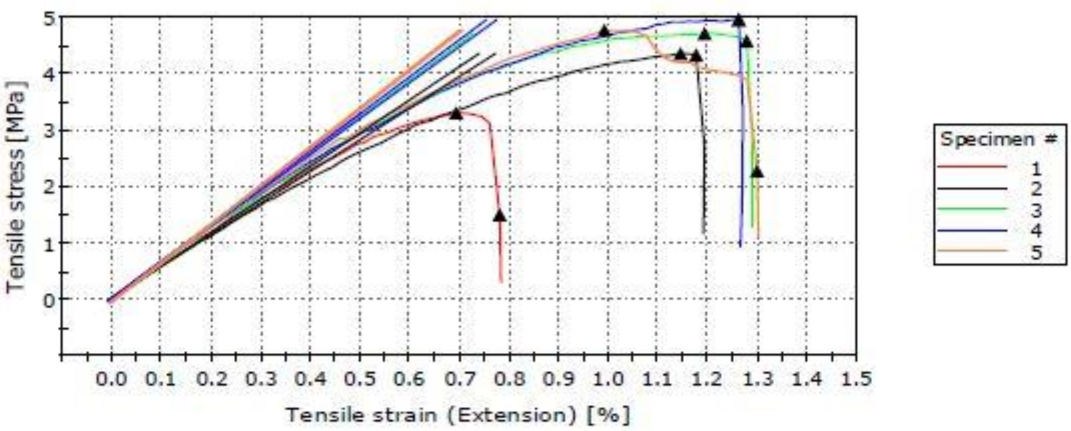
	Maximum Load [N]	Tensile stress at Maximum Load [MPa]	Load at Yield (Zero slope) [N]
1	275.49	7.06	275.49
2	292.32	7.50	292.32
3	271.28	6.96	271.28
4	282.00	7.23	282.00
5	255.80	6.56	255.80

	Tensile stress at Yield (Zero slope) [MPa]	Load at Break (Standard) [N]	Tensile stress at Break (Standard) [MPa]
1	7.06	273.05	7.00
2	7.50	290.47	7.45
3	6.96	270.10	6.93
4	7.23	280.91	7.20
5	6.56	212.78	5.46

	Modulus (Automatic Young's) [MPa]	Modulus (Automatic) [MPa]
1	639.50	625.14
2	657.20	641.27
3	625.84	596.26
4	666.75	622.96
5	605.11	605.90

Tensile Test for KENAF_PP

50% Kenaf + 50% PP



	Maximum Load [N]	Tensile stress at Maximum Load [MPa]	Load at Yield (Zero slope) [N]
1	129.14	3.31	-----
2	169.99	4.36	-----
3	183.83	4.71	-----
4	193.17	4.95	-----
5	186.01	4.77	-----

	Tensile stress at Yield (Zero slope) [MPa]	Load at Break (Standard) [N]	Tensile stress at Break (Standard) [MPa]
1	-----	58.97	1.51
2	-----	169.00	4.33
3	-----	178.64	4.58
4	-----	193.17	4.95
5	-----	89.17	2.29

	Modulus (Automatic Young's) [MPa]	Modulus (Automatic) [MPa]
1	641.33	653.99
2	586.45	558.65
3	680.08	647.08
4	652.30	632.83
5	685.04	678.04

APPENDIX D

Composite	Tensile Stress (MPa)					
	1st	2nd	3rd	4th	5th	Average
80% Polypropylene 20% Kenaf	9.110	6.480	6.890	8.950	7.510	7.788
70% Polypropylene 30% Kenaf	7.820	7.250	7.770	8.010	8.000	7.770
60% Polypropylene 40% Kenaf	7.060	7.500	6.960	7.230	6.560	7.062
50% Polypropylene 50% Kenaf	3.310	4.360	4.710	4.950	4.770	4.420

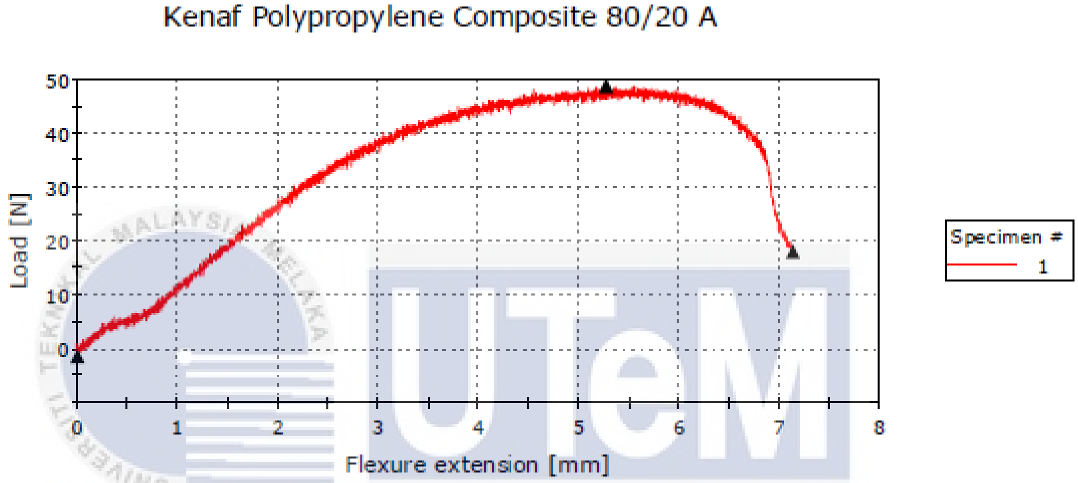
APPENDIX E

FLEXURAL STRESS

Kenaf Polypropylene Composite

Kenaf Polypropylene Composite

Specimen properties: Thickness	3.00000 mm
Specimen properties: Width	12.70000 mm
Specimen properties: Support span	48.00000 mm
Test: Rate 1	1.28000 mm/min

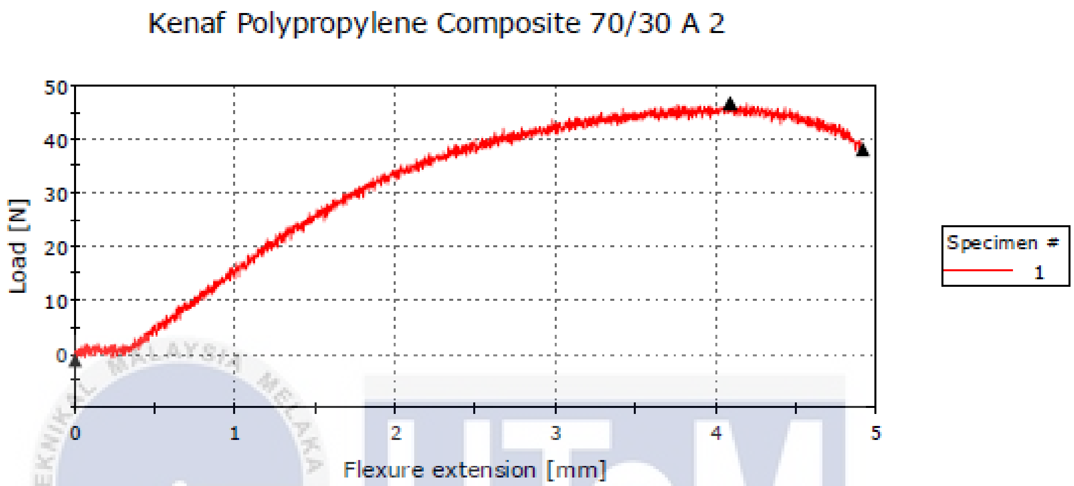


	Maximum Load [N]	Flexure stress at Maximum Load [MPa]	Flexure extension at Maximum Load [mm]	Flexure strain (Extension) at Maximum Load [mm/mm]
1	48.709	30.683	5.272	0.04118

Kenaf Polypropylene Composite

Kenaf Polypropylene Composite

Specimen properties: Thickness	3.00000 mm
Specimen properties: Width	12.70000 mm
Specimen properties: Support span	48.00000 mm
Test: Rate 1	1.28000 mm/min

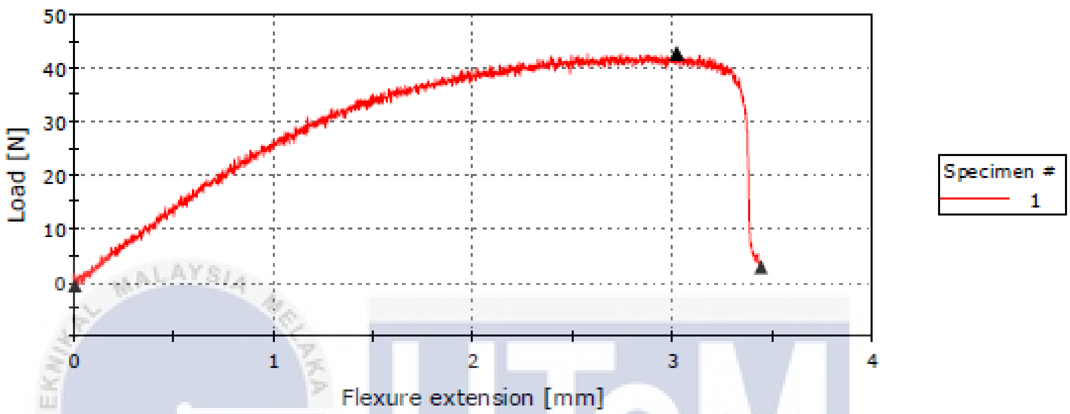


	Maximum Load [N]	Flexure stress at Maximum Load [MPa]	Flexure extension at Maximum Load [mm]	Flexure strain (Extension) at Maximum Load [mm/mm]
1	46.629	29.372	4.083	0.03190

Kenaf Polypropylene Composite

Kenaf Polypropylene Composite

Specimen properties: Thickness	3.00000 mm
Specimen properties: Width	12.70000 mm
Specimen properties: Support span	48.00000 mm
Test: Rate 1	1.28000 mm/min

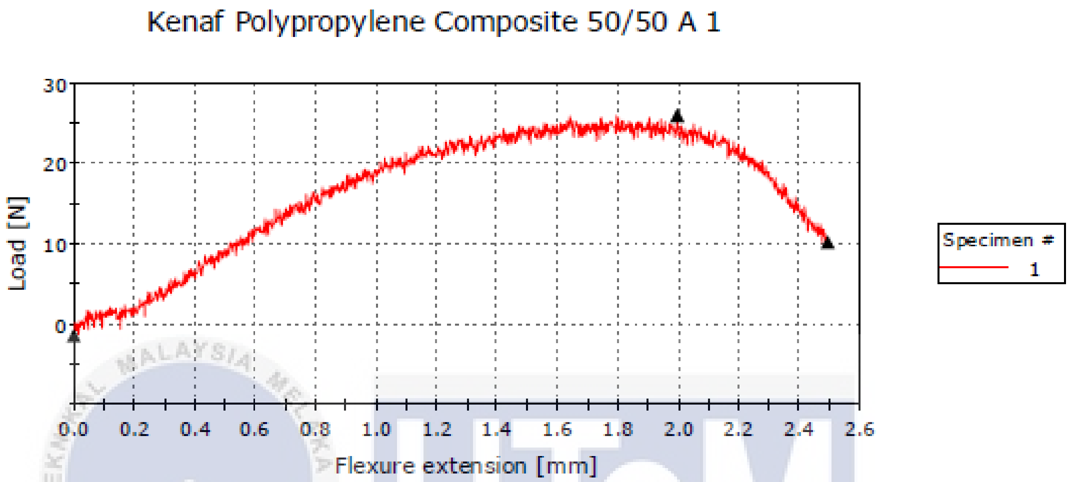


	Maximum Load [N]	Flexure stress at Maximum Load [MPa]	Flexure extension at Maximum Load [mm]	Flexure strain (Extension) at Maximum Load [mm/mm]
1	42.668	26.878	3.017	0.02357

Kenaf Polypropylene Composite

Kenaf Polypropylene Composite

Specimen properties: Thickness	3.00000 mm
Specimen properties: Width	12.70000 mm
Specimen properties: Support span	48.00000 mm
Test: Rate 1	1.28000 mm/min



	Maximum Load [N]	Flexure stress at Maximum Load [MPa]	Flexure extension at Maximum Load [mm]	Flexure strain (Extension) at Maximum Load [mm/mm]
1	26.002	16.379	1.993	0.01557

APPENDIX F

Composite	Flexural Stress (MPa)					
	1st	2nd	3rd	4th	5th	Average
80% Polypropylene 20% Kenaf	30.683	33.460	31.473	33.304	30.044	31.793
70% Polypropylene 30% Kenaf	-	29.372	-	31.849	32.467	31.229
60% Polypropylene 40% Kenaf	26.878	29.064	26.495	27.194	28.942	27.715
50% Polypropylene 50% Kenaf	16.379	21.963	18.039	13.534	16.093	17.202

APPENDIX G

DETAIL CALCULATION FOR THERMAL CONDUCTIVITY

- **20% Kenaf 80% PP**

$$\dot{Q} = kA\frac{\Delta T}{\Delta X}$$

$$k = \frac{\dot{Q}}{A}\frac{\Delta X}{\Delta T}$$

$\dot{Q} = 150W$ $A = \frac{\pi}{4}(0.115)^2$ $\Delta X = 0.006m$ $\Delta T = 76.0 - 64.0$

= $0.0104 m^2$ = 12.0 ℃

$$k = \frac{150\ x\ 0.006}{0.0104\ x\ 12.0}$$

= 7.211 W/m•K

- **30% Kenaf 70% PP**

$$\dot{Q} = kA\frac{\Delta T}{\Delta X}$$

$$k = \frac{\dot{Q}}{A}\frac{\Delta X}{\Delta T}$$

$\dot{Q} = 150W$ $\quad A = \frac{\pi}{4}(0.115)^2$ $\quad \Delta X = 0.006m$ $\quad \Delta T = 78.0 - 64.0$

= $0.0104 m^2$ $\quad$ = 14.0 ℃

$$k = \frac{150\ x\ 0.006}{0.0104\ x\ 14.0}$$

= 6.181 W/m•K

- **40% Kenaf 60% PP**

$$\dot{Q} = kA\frac{\Delta T}{\Delta X}$$

$$k = \frac{\dot{Q}}{A}\frac{\Delta X}{\Delta T}$$

$\dot{Q} = 150W$ $\quad A = \frac{\pi}{4}(0.115)^2$ $\quad \Delta X = 0.006m$ $\quad \Delta T = 90.0 - 74.0$

= $0.0104m^2$ = 16.0 ℃

$$k = \frac{150\ x\ 0.006}{0.0104\ x\ 16.0}$$

= 5.409 W/m•K

- **50% Kenaf 50% PP**

$$\dot{Q} = kA\frac{\Delta T}{\Delta X}$$

$$k = \frac{\dot{Q}}{A}\frac{\Delta X}{\Delta T}$$

$\dot{Q} = 150W$ $A = \frac{\pi}{4}(0.115)^2$ $\Delta X = 0.006m$ $\Delta T = 94.0 - 76.0$

$= 0.0104\text{m}^2$ $= 18.0\ ℃$

$$k = \frac{150\ x\ 0.006}{0.0104\ x\ 16.0}$$

$= 4.808$ W/m•K

APPENDIX H

Gantt Chart for PSM 1

No.	Topic	Weeks													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.	Working Time for PSM 1														
2.	Topic Selection														
3.	Topic Confirmation														
4.	Introduction of Kenaf and Polypropylene composite														
5.	Information Gathering														
6.	Preparation of Introduction														
7.	Preparation of Literature Review														
8.	Preparation of Methodology														
9.	Correction of Report														
10.	Submission of Report														

Gantt Chart for PSM 2

No.	Topic	Weeks													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.	Working Time for PSM 2	■	■	■	■	■	■	■	■	■	■	■	■	■	
2.	Raw Material Finding	■	■												
3.	Specimen Fabrication			■	■	■	■								
4.	Specimen Fitting							■	■	■	■	■			
5.	Specimen Testing									■	■	■	■	■	
6.	Modification of Methodology									■	■	■	■		
7.	Preparation of Results and Discussion										■	■	■	■	
8.	Preparation of Conclusion													■	
9.	Correction of Report and Compilation													■	
10.	Submission of Report														■