Faculty of Mechanical and Manufacturing Engineering Technology

PARAMETER OPTIMIZATION OF KENAF FIBER FOR HEAT INSULATOR

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PARAMETER OPTIMIZATION OF KENAF FIBER FOR HEAT INSULATOR

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DEDICATION

Dedicated to
my beloved mother, Sariah binti Lasa
my late father, Abdul Ghani binti Ali Kamaruddin
my adored siblings, Nuraimi, Nur Hakimah, Nur Hamizah
my beloved niece, Nur Aleeya Zara binti Muhd Firdaus Shah
my future fiancé, husband and life partner, Abd Rashid bin Ab Wahab
Thank You So Much for All the Support & Love You All Forever

ABSTRACT

Nowadays, awareness towards environment increase significantly, people has learned the importance of protecting the environment for the better future. The pipe that carried high temperature liquid will release heat to the surrounding and causing the surrounding temperature increased. Thus, the insulation system is important to ensure that the heat is contain within the insulation system. The disposal of synthetic fiber is become concern due to requirement of change the heat insulator after certain period of time for example each five years. This study was conducted to investigate the potential of non-woven kenaf fiber as heat insulator to replace synthetic fibre. The objective of this study is to identify the optimum layup sequence of the composite that will insulate heat that reach up to 250 °C (at high elevated temperature) at prolonged. Non-woven kenaf fiber will be used along with polyurethane in this study. The non-woven kenaf fiber and polyurethane is arranged with different layup sequence using sandwich method. The result reveal that S11 with the layup sequence of PKKKKKKKKKPKP possess the lowest heat flow with the difference of 45.25 % compared to glass wool. While S3 with the layup sequence of PKPKKKKKKKKKP possess the lowest thermal conductivity with 42 % improvement compared to glass wool. The usage of non-woven kenaf fiber as heat insulator will help to reduce cost and environment issue. The potential to commercialize is high due to their ability to replace synthetic fiber in term of low thermal conductivity especially for high temperature pipe.

ABSTRAK

Pada masa kini, kesedaran terhadap alam sekitar meningkat dengan ketara, orang ramai telah mempelajari kepentingan melindungi alam sekitar untuk masa depan yang lebih baik. Paip yang membawa cecair suhu tinggi akan melepaskan haba ke persekitaran dan menyebabkan suhu persekitaran meningkat. Oleh itu, sistem penebat adalah penting untuk memastikan bahawa haba terkandung di dalam sistem penebat. Pelupusan serat sintetik menjadi keprihatinan karena keperluan menukar penebat panas setelah jangka waktu tertentu seperti setiap lima tahun. Kajian ini dijalankan untuk mengkaji potensi serat kenaf bukan tenunan sebagai penebat haba untuk menggantikan serat sintetik. Objektif kajian ini adalah untuk mengenalpasti susunan lapisan optimum komposit yang akan melindungi haba yang mencapai 250 °C (pada suhu tinggi yang meningkat) yang berpanjangan. Serat kenaf bukan tenunan akan digunakan bersama dengan polyurethane dalam kajian ini. Serat kenaf bukan tenunan dan *polyurethane* disusun dengan urutan peletakan yang berbeza menggunakan kaedah lapisan. Hasilnya mendedahkan bahawa S11 dengan susunan urutan PKKKKKKKKKPKP mempunyai aliran haba terendah dengan perbezaan 45.25 % dibandingkan dengan gentian kaca. S3 dengan urutan layang PKPKKKKKKKKKP mempunyai daya pengaliran terma yang paling rendah dengan peningkatan 42 % berbanding gentian kaca. Penggunaan serat kenaf bukan tenunan sebagai penebat haba akan membantu mengurangkan isu kos dan persekitaran. Potensi untuk dikomersialkan tinggi kerana kemampuan mereka untuk menggantikan serat sintetik dari segi daya pengaliran terma yang rendah terutamanya untuk paip suhu tinggi.

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LIST OF ABBREVIATION

PU	-	Polyurethane
NFPC	-	Natural fiber reinforced composite
ASTM	-	American standard testing material
SiC	-	Silicon Carbide
TGA	-	Thermal gravity analysis
NWK	-	Non-woven kenaf fiber
LKTN	-	Lembaga Kenaf dan Tembakau Negara
SIP	-	Structural insulation panel

LIST OF SYMBOLS

°C	-	Degree Celsius
°F	-	Degree Fahrenheit
W/m.k	-	Watts per meter-Kelvin
k	-	Conductivity
kg	-	Kilogram
mm	-	Millimeter
cm	-	Centimeter
ton	-	Tonne
N	-	Newton
K	-	Kelvin
ρ	-	Density
λ	-	Thermal conductivity
K	-	Kelvin
dT	-	Temperature difference
R	-	Resistance
L	-	Thickness

CHAPTER 1

INTRODUCTION

This chapter will explain and clarify about background, characteristic and behaviour of natural fibre, polymer based matrix act as heat insulation for fixed temperature. This research is an idea that consist of fundamental theory on past research, book, journal and online sources. Hence the information and issue are gathered to identify the improvement needed for this research.

1.1 Background

For the past few decades, interest in natural fiber reinforced composite (NFRC) has resurged, resulting in voluminous research and new usage as industrial application. Composite is the combination of two or more material to produce another new material which consist of their original characteristic that improved (Jones, 2014; Barbero, 2017; Abramovich, 2017). Interest in NFRC is growing for many reasons including their potential to replace synthetic fiber reinforced plastics at lower cost with improved sustainability. Their advantages include low density and high specific strength and stiffness, also they known as renewable resources in which production require small amount of energy (Pickering *et al.*, 2016). The performance of these composites has improved continuously through several research, often through mixing of two or more reinforcements and polymers or fillers as mentioned by Ramesh (2018). Pickering *et al.* (2016) mentioned that natural fiber consists of three different categories which is cellulose from plant, protein from animal and mineral. Plant based cellulose came from different type of origin such as reed, bast, leaf, and stalk.

According to Ramesh (2016), kenaf fiber or long fiber is extracted from bast and particle is extracted from core. Kenaf has gain attention due to their compatibility with various type of soil and able to growth under wide range of climate conditions, cellulose came from bast and core contain different properties (Sapuan *et al.*, 2018), the available type of reinforcement as supplied by *Lembaga Kenaf dan Tembakau Negara* (LKTN) are particulate and fibrous. Saba *et al.* (2015) presented a comprehensive review on different type of kenaf reinforcement, they found that non-woven kenaf fiber that using hand layup as fabrication technique has the highest specific energy absorption capability which equal to 9.2 J/g. This research will focus on non-woven type of reinforcement due to its capability in absorbing energy such as heat.

Polymer matrix embedded with high-strength natural fibres are considered as natural fiber polymer composites (NFPC), polymer matrix usually divided into two distinct type which is thermoset and thermoplastic. Thermoset polymer is highly cross-linked polymer can be cured using three different method which is only heat is applied, other method is combination of heat and pressure with and without light irradiation. Thermosets have outstanding resistance toward heat, solvents, and mechanical deformations as quote by Vengatesan *et al.* (2018) and thermoset contains good properties for instance high flexibility for tailoring desired ultimate properties due to their structure (Mohammed *et al.*, 2015), they added that the hydrophilic nature of the natural fiber and filler of fiber can affect the properties of composites. Hence, the good properties of NFPC's can be obtained by using more filler.

In other hand, kenaf has huge potential due to their closed porous structures causing the blowing agent gas with extremely low thermal conductivity trapped. This ability makes polymetric foams as one of the most effective thermal insulation materials (Zhang *et al.*, 2017). Then they emphasise that polyurethane (PU) foams is one of the family members of thermoset polymer make the most efficient thermal insulation material, by considering their thermal conductivity where the value is between 0.02 and 0.03 W/mK. Hence, polyurethane is considered to be one of the matrices used in this research.

Thermal conductivity in polymers may be achieved either by molecular orientation and mentioned that thermal conductivity will slightly decrease when the direction perpendicular to the orientation (Kumlutas and Tavman, 2006). According to Chen *et al.* (2016) thermal conductivity depend on several factors including polymer type in which the loading level and filler shape and size. Aside from polymer type, the dimensional arrangement and orientation of the filler also played an important role to minimize or maximize thermal conductivity.

Kenaf reinforced Polyurethane (PU) and Natural rubber (NR) research had been done by Azammi *et al.* (2018), by using thermal gravimetric analysis (TGA) and they found that polymer composite achieves 320 °C before degradation, the composition of PU is increase and its increase the temperature before degradation, almost all composition shared the same peak which is up to 600 °C. However, the researcher does not mention the type of kenaf fiber used. Hence, it can be concluded that there is not enough research on non-woven kenaf fiber and polyurethane using sandwich method.

1.2 Problem Statement

For the past few decades, there are vast researcher focused on natural fiber composite since it seen to have potential in replacing synthetic fiber composite (Ramesh, 2016; Pickering *et al.,* 2016). There are several contradict result from different researcher on natural fiber composite on their mechanical and thermal characteristic which are meant to be used as engineering application. however, there are minimum amount of research that focus on minimizing thermal conductivity of kenaf fibre. Azammi *et al.* (2018) stated that a good composite contains an ability to absorb energy also high on tensile and flexure strength. Different proportion of reinforcement and binder also gave different result as stated by Chen *et al.* (2016). They stated that high filler loading not only will cause brittleness to the composite but also increase the thermal conductivity of composites.

It is crucial to select the suitable matrix to ensure that the thermal stability of kenaf fiber are maintaining their properties. According to Ramesh *et al.* (2018), they found that fiber loadings will decrease mechanical properties of composites such as flexural, tensile and impact strength properties while increase in tensile modulus. The optimum stress-strain behaviour is when the composite contains 20 % of fibre. El-Shekeil *et al.* (2012), found that 30 % is the optimum fiber content for tensile strength however, they stated when the fiber loading was increased it will increase the hardness but will decrease the abrasion resistance and thermal stability. Unfortunately, in their study there are no declaration on which type of kenaf fiber used whether non-woven, woven and long fibre.

Azammi (2016) mentioned that kenaf fiber could withstand the heat until 200 °C and its cellulose start decompose at temperature 300 to 350 °C. Even though kenaf fiber itself can withstand heat however kenaf fiber reinforced polymer composite possesses better thermal stability. Thermoset polymer is the members of polymer composites which still active in engineering area for developments and modifications to broadens their application range. According to Vengatesan (2018) The thermal properties of thermosets have further improvement through structural or compositional modifications of precursors.

On the other hand, Thickness played an important role to ensure that the heat stayed between the desired region, however with the increasement of heat insulator thickness will also increase the cost as quoted by Daşdemir *et al.* (2017a), their findings shown that the optimum thickness for steel and copper pipes varies from 5-16 cm and 5-12 cm respectively which also applicable for larger pipe diameter. In Daşdemir *et al.* (2017b) stated that the usage of air gap between insulator and pipe can help improve the insulation ability, the result also shown the lowest insulator thickness. Hence the thickness for this research will stay in between range to ensure that optimum insulation can be achieved under range stated and all probability will be taken into consideration.

According to Hayashi *et al.* (1992) due to difficulties to attach the conventional plastic foam insulator to pipes massive time and money will be consumed, the usage of shape memory that will mould insulator into desire shape which has good moldability. In 2018, Tsuchiya *et al.* stated that the problem arise in heat insulator for pipeline is when the pipe having a bending part, this is where when thermal expansion occur on pipe however does not occur on heat insulator material.

Hydrophobic blanket thermally insulates better than mineral wool, it is equal in insulating properties to untreated fibreglass mat however insulate slightly than aerogel based blanket materials. The ability to withstand heat for a long period of time is 315 °C as stated by Dill and Zhou (2018). As the result found by Li *et al.* (2016) aramid fiber reinforced aerogels (AF/aerogels) possessed extremely low thermal conductivity of 0.0227 ± 0.0007 $Wm^{-1} K^{-1}$ due to the softness, low density and remarkable mechanical strength of aramid fibres and the layered structure of the fiber distribution. The AF/aerogels presented nice elasticity and flexibility. The thermal stability reaching approximately 290 °C. However, the usage of synthetic fiber will always cost higher than natural fibre.

Currently, the awareness towards environment increase, one of the efforts that can be done is to replace current synthetic fiber for heat insulator into natural fibre. For the past few years many researchers had conduct the study on various type of natural fiber that can be used to replace synthetic fiber namely coconut fiber (Iwaro and Mwasha, 2019; Kumar, 2018; Chuen *et al*., 2015), palm fiber (Ali and Alabdulkarem, 2017), polyester fiber (Li *et al*., 2016) and many more. An experimental investigation will be conducted to explore the most suitable parameter of non-woven kenaf reinforced polyurethane and non-woven reinforced natural rubber latex as heat insulator.

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1.3 Objectives

The objective of this research as follows:

(a) To fabricate the heat insulator made from non-woven kenaf fiber with polyurethane foam by using sandwich method.

(b) To investigate material composition and their behaviour towards high temperature.

(c) To propose the best layup sequence for optimum performance.

1.4 Scopes

Limitation of this research are as follows:

(a) To study the most potential of thermoset polyurethane to be used by considering the processing temperature and cost.

(b) The study will be conducted to see the potential of layup sequence of NWK and PU to be used as heat insulator.

(c) To identify the suitable amount of composition of kenaf and binder to produce a good insulator.

(d) To ensure that heat insulator able to withstand a temperature up to 300°C before degradation

(e) To study the properties of composite when different ratio of kenaf fiber and polyurethane

(f) The testing will be made to investigate the relationship between kenaf fiber and polyurethane and their ability to absorb energy and resist heat