

SIMULATION AND APPLICATION OF NATURE FIBER/POLYESTER ALUMINUM HONEYCOMB FOR THERMAL ANALYSIS FOR MALAYSIAN SHELTER APPLICATION



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Muhammad Amin Shafiq Bin Mohd Ramli

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Simulation And Application Of Nature Fiber/Polyester Aluminum Honeycomb For Thermal Analysis For Malaysian Shelter Application

MUHAMMAD AMIN SHAFIQ BIN MOHD RAMLI



Faculty of Mechanical and Manufacturing Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2023

DECLARATION

I declare that this thesis entitled "Simulation And Application Of Nature Fiber/Polyester Aluminum Honeycomb For Thermal Analysis For Malaysian Shelter Application" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.



APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (Refrigeration And Air Conditioning Systems) with Honours.

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Signature	: .	
Supervisor	ame : Dr. Muhammad Zulkarnain	
Date	: 20 January 2023	
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DEDICATION

This dissertation is dedicated to my beloved parents Mohd Ramli Bin Muda and Kamariah Binti Jusoh, my family, and my friends whose unyielding love, support, and encouragement have enhanced my soul and inspired me to pursue and complete this research during a pandemic.



ABSTRACT

Humans have used composites for thousands of years. Nowadays, application of composites more used widely in many types of industrial. A composite material is a solid material that is formed by the combination of two or more distinct substances, each of which has its own set of properties, to produce a new substance that has properties that are superior to those of the original components in a particular application. In addition, composites obtain their extraordinary qualities by encasing fibers of one substance within the matrix of another substance, which serves as the host. The composites material consists aluminium honeycomb as core along the sheets panel (upper and lower) and nature fiber reinforced as adhesive. Material properties of the nature fibers and aluminium research has been done. Unfortunately, Malaysia has witnessed some of its worst floods for a long time. Many people have been physically and emotionally impacted as a result. Several of them experienced property damage and losses. Those who have lost their houses must find the designated flood refuge. Undoubtedly, the shelter will be full, as well as some refugees may have to remain in tents outside the shelter. The material of the tents was insufficient to shield and comfort the refugees from all weather conditions, especially extreme hot. In order to overcome the problems, modelling and assembly 3D nature fiber reinforcement honeycomb which sheet panel composite as skin while aluminium honeycomb as core using SOLIDWORKS. The 3D model has exported into ANSYS to perform simulation testing of material properties especially the thermal conductivity. Through the simulation testing, the most effective thermal conductivity of nature fibers can be determined correspond with previous research. of thermal analysis. A new composite material can be identified in order to produce material of tents with most effective thermal conductivity for flood refugees. 0.6

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ABSTRAK

Manusia telah menggunakan komposit selama beribu-ribu tahun. Pada masa kini, aplikasi komposit lebih digunakan secara meluas dalam pelbagai jenis industri. Bahan komposit ialah bahan pepejal yang terbentuk daripada gabungan dua atau lebih bahan yang berbeza, setiap satunya mempunyai sifatnya sendiri, untuk menghasilkan bahan baru yang mempunyai sifat vang lebih baik daripada komponen asal dalam sesuatu tertentu aplikasi. Selain itu, komposit memperoleh kualiti luar biasa mereka dengan membungkus gentian satu bahan dalam matriks bahan lain, yang berfungsi sebagai perumah. Bahan komposit terdiri daripada sarang lebah aluminium sebagai teras di sepanjang panel kepingan (atas dan bawah) dan gentian alam semulajadi yang diperkukuh sebagai pelekat. Sifat bahan gentian alam semulajadi dan penyelidikan aluminium telah dilakukan. Malangnya, Malaysia telah menyaksikan beberapa banjir terburuknya sejak sekian lama. Ramai orang telah terjejas secara fizikal dan emosi akibatnya. Beberapa daripada mereka mengalami kerosakan dan kerugian harta benda, Mereka yang kehilangan rumah mesti mencari tempat perlindungan banjir yang ditetapkan. Tidak dinafikan, tempat perlindungan akan penuh, begitu juga sesetengah pelarian mungkin terpaksa tinggal di khemah di luar tempat perlindungan. Bahan binaan khemah tidak mencukupi untuk melindungi dan memberi keselesaan kepada pelarian daripada semua keadaan cuaca, terutamanya panas melampau. Bagi mengatasi masalah tersebut, pemodelan dan pemasangan sarang lebah tetulang gentian alam semulajadi 3D yang panel lembaran komposit sebagai kulit manakala sarang lebah aluminium sebagai teras menggunakan SOLIDWORKS. Model 3D telah dieksport ke dalam ANSYS untuk melakukan ujian simulasi sifat bahan terutamanya kekonduksian haba. Melalui ujian simulasi, kekonduksian haba gentian alam semulajadi yang paling berkesan boleh ditentukan sepadan dengan penyelidikan analisis haba terdahulu. Bahan komposit baharu boleh dikenal pasti untuk menghasilkan bahan khemah dengan kekonduksian haba paling berkesan untuk pelarian banjir.

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composite with difference fiber volume fraction



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LIST OF SYMBOLS AND ABBREVIATIONS

- k Effective thermal conductivity
- q Heat flow
 - Length of side wall
- t1,t0

L

- Temperatures at the borders
- مراجع مراج مراجع مراحم مراجع مراجع مراجع مراجع مراجع مراجع مراجع مراجع مراجع مراطع مراطع
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CHAPTER 1

INTRODUCTION

1.1 Background

A composite material is a solid material that is formed by the combination of two or more distinct substances, each of which has its own set of properties, to produce a new substance that has properties that are superior to those of the original components in a particular application. Another name for this type of material is a composite. Composites are also known as composite materials. To be more precise, the term "composite" refers to a material for building that has been combined with other components.

In addition, composites obtain their extraordinary qualities by encasing fibers of one substance within the matrix of another substance, which serves as the host. Although the structural value of a bundle of fibers is modest, the strength of individual fibers may be used if they are immersed in a matrix that serves as an adhesive and binds the fibers together to give the material its solidity. This method is known as matrix-encapsulation. The stiff fiber is what provides the composite its structural strength, while the matrix is what shields the fiber from environmental stress and physical damage, in addition to providing them with thermal stability (Britannica, 2022).

These days, honeycomb sandwich has been supplied high performance for mechanical strength with linear to light weight. Sandwich constructions have a core and layers of material, and honeycomb sandwich is one type of sandwich. They make it possible to improve the mechanical qualities without significantly increasing the weight of the material. Additionally, they strengthen the insulation against heat and sound. Indirectly, honeycomb sandwich structural have been selected for this application of Nature Fiber/Polyester Aluminum honeycomb for Thermal Analysis for Malaysian Shelter because it is related and suitable with the research that is focusing on thermal analysis. This contrasts with the monolithic constructions, which are made up of overlapping fabrics with certain orientations and have a more intricate geometry. Because components of this sort are supposed to be able to endure the greatest possible loads on the structure, they are not appropriate for use in the research.



Figure 1.1 Disasters due to floods

The danger rating for a tsunami striking Malaysia in 2020 was 7,1 out of a possible 10, while the chance of floods was 6,6. Since 2003, Malaysia has witnessed some of its worst floods as illustrated in Figure 1.1, with over 6,000 people impacted by flash floods and landslides caused by flooding in 2017 (Statista, 2019). This statistic indicates that natural disasters occur often in our country. Many people have been physically and emotionally impacted as a result. Several of them experienced property damage and losses. Those who have lost their houses must find the designated flood refuge.

Undoubtedly, the shelter will be full, as well as some refugees may have to remain in tents outside the shelter. The material of the tents was insufficient to shield and comfort the refugees from all weather conditions, especially extreme hot. Therefore, these new composite materials will be more effective in terms of durability, weight, and heat resistance. Thus, despite remaining in the tent, the refugees will experience greater comfort.

1.2 Problem Statement

It is underliable that our country is always surprised by natural disasters that hit, especially severe floods. Every year, many places and people have been affected by floods. This cannot be dammed because it is a natural disaster in this world and must be faced by every resident. Indirectly, the victims who have lost their homes must be moved to the flood reserved center for temporary placement. Sometimes, because too many refugees are placed in the center, the place will be crowded and half of them have to be placed in tents. There are various age groups among the refugees including infants and the elderly. Therefore, their temporary shelter should be comfortable in various aspects.

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Naturally the climate in our country is always changing, especially warm and cold weather. This will affect the refugees and give them discomfort throughout their stay in the tent. To overcome this problem, research have been carried out related to thermal analysis for Malaysian Shelter Application by develop 3D sandwich honeycomb model simulation for random natural fiber composite and their thermal conductivity of the material.

1.3 Research Objective

The aim of this research is to build a tent that contains a new composite material which being produce to provide a convenience, comfortable and affordable for the victim as a shelter. Two objectives are made in order to achieve the aim of this project which is:

- a) To develop 3D sandwich model of thin-walled honeycomb with nature fiber composite panel using fiber random distribution method.
- b) To investigate thermal conductivity performance by varied nature fiber component content.
- 1.4 Scope of Research

The scope of this research are as follows:

- a) Varied nature fiber reinforcement honeycomb which sheet panel composite as skin while aluminium honeycomb as core. Natural fiber is randomly distributed in longitudinal direction was developed in 3D simulation. The research limited by longitudinal fiber direction is considered during thermal analysis.
- b) Varied nature fiber will be embedded randomly to achieve thermal conductivity for the composite material structure.
- c) The material testing process will be subjected on each new composite material that selected.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, it is clarified about presentation composite material of Nature Fiber/Polyester Aluminum honeycomb in order to select the best nature fiber reinforced polyester for thermal analysis with a high level of user satisfaction attributes. This section contains about all discoveries obtained from literature reviews reacarch on nature fiber and polyester, composite material, honeycomb, material selection, materials and methods, and thermal analysis of nature fiber reinforced polymer composite, which derived from the journals, article, internet, and the book that has the related topic to this study.

2.2 Nature Fiber and Polyester

2.2.1 Nature Fiber

The awareness among people regarding the advantages of natural products has steered the use of natural resources. Nature fibers are any raw materials with a hairlike structure that can be obtained directly from a vegetable (cellulose), animal or mineral source and can be transformed into nonwoven textiles like as felt or paper or spun into yarns and then woven into fabric. Figure 2.1 shows an example of a nature fiber in this context. An additional definition of a nature fiber may be that it is an aggregation of cells in which the diameter is insignificant in proportion to the length (Gholampour and Ozbakkaloglu, 2020). Despite the abundance of fibrous materials in nature, like wood, cotton, grains, and straw, just a handful of them may be used for textile manufacture or other industrial purposes.

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Figure 2.1 Different types of nature fibers

Nature fibers have been used to make textiles from the beginning of time. Figure 2.2 displays the discovery of flax and wool fabrics in Swiss lake dwellings dating back to the 7th and 6th centuries BCE. Prehistoric peoples also made use of a wide range of plant fibers. It is widely accepted that hemp was first grown in Southeast Asia and then spread to China, where it has been farmed from at least 4500 BCE, as according historical evidence. By 3400 BCE, Egyptians were already weaving and spinning linen, indicating that flax had been grown before this time. Cotton spinning dates back to 3000 BCE in India. 2640 BCE is the earliest known date of sericulture (silkworm farming) and silk spinning techniques, which were developed in the highly advanced Chinese civilization (Keya et al., 2019).



Figure 2.2 History of nature fiber and manmade fiber

There was a real risk to the monopoly of natural fibers in the textile and industrial sectors due to the development of regenerated cellulosic fibers (fibers made from cellulose fibers that has been dissolved, cleaned, and extruded), such as rayon (Textile School, 2018). Nature fibers had previously controlled the market, but other synthetic fibers with desirable properties started to invade and take over. Researchers have spent a lot of time and money trying to find new and better natural fiber sources that can produce more fibers, improve manufacturing and processing procedures, and modify the properties of fiber yarn or fabric. The share of the market of natural fibers has decreased, regardless of the fact that total output has increased as a consequence of substantial breakthroughs in fiber manufacturing.

Numerous investigations on the functionalization of nature fibers have been reported as being conducted in the pursuit of high-performance levels in composite materials that are reinforced with nature fibers. The functionalization of nature fibers can be accomplished by a variety of processes, the most common of which are classified as either physical or chemical alterations (Wilson, 2011). Polymer interactions and wettability, as well as water resistance, antimicrobial characteristics and thermal stability are all aspects of functionalization that may be summarized. Functionalization may lead to a wide range of effects, including these. Nature fibers may be physically functionalized using treatments like stretching, calendaring, the thermos treatments, electronic discharges from corona and plasma sources, and the development of hybrid yarns (Kilinç et al., 2017).

Besides economic considerations, a fiber's usability for industry sectors is dependent on its length, pliability and other properties such as its elasticity, abrasion resistance and absorbency. Thick, flexible, and fairly strong fibers make up the bulk of textiles (Anish M. Varghese, 2017). They are elasticity in the concept that they back into its original length when they are exposed to strain, either partly or completely.

2.2.2 Polyester

The Federal Trade Commission defines polyester as a synthetic fiber with a long chain that contains 85% by volume of an ester of a substituted aromatic carboxylic acid. Polyester is a synthetic fiber. PHT (poly(ethylene terephthalate)) and PEN (poly(ethylene naphthalate)) are the most common polyesters. The worldwide fibre industry, which involves both man-made and natural fibers, has been dominated by polyester over the last several decades. Polyethylene accounted for about 69% of the total fiber utilization in 2017, according to Figure 2.3. The three major polyester producers in the world are Dupont, Hoechst, and Eastman (Azlin *et al.*, 2020). Wastes account for approximately 3–5% of overall output in the PET fiber manufacturing process. PET does not disintegrate for a long period in nature. The waste of PET is important since it is a petroleum derivative, and it must be recycled for economic and environmental reasons.



Figure 2.3 World consumption of polyester fiber

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When polyester was introduced in 1941, it quickly became the most often used fabrics. It's been made commercially since 1947, and it's found in a wide range of businesses. Since 1990, the annual growth rate of global polyester consumption has been continuously recorded around 7%. With the addition of polyester, cotton's shrunk, durability, and wrinkling qualities are enhanced. Polyester is a weather-resistant fabric that is ideal for long-term outdoor use (Sewport, 2022). PET fibers have been particularly successful due to a number of features, including their lower cost, ease of processing, simple recyclability, and ability to mix with natural-based fibers.

2.2.3 Classification of Nature Fibers

Nature fiber origins can be utilized to categorize these materials. Cotton, flax, and jute are examples of vegetable (cellulose) fibers. Animal (protein) fibers include wool, mohair, and silk. Asbestos is a major mineral fiber of the mineral class. Figure 2.4 helps to simplify the nature fibers classification.

Figure 2.4 Schematic of nature fibers classification (Neto et al., 2021)

2.2.3.1 Vegetable (Cellulose)

Vegetable fibers are made up mostly of cellulose, a chemical compound. In plants, the fibers are made of cellulose, which is a kind of cellulosic fiber. Plant fiber is another name for vegetable fiber, which is obtained from plants. Cotton, hemp, jute, flax, banana, sisal and ramie are examples of cellulose-based vegetable fibers (Kiciska-Jakubowska et al., 2012) as illustrated in Figure 2.5.

Ancient man employed vegetable fibers for fishing and trapping. They fashioned ropes and cords as early as 20,000 B.C., according to evidence. Around 4000 B.C., the Egyptians most

likely made ropes and cords out of reeds, grasses, and flax. Dietary fiber is an essential part of human nutrition, and paper and textiles (clothing) are created from plant fibers. Prior to the Industrial Revolution, spinning and weaving were commonplace household activities, and the processing of fibers into textiles, such as tent fabric, remained a household business. It was a skilled activity carried out by working people who passed their expertise down from generation-to-generation (Textile Learner, 2021).

Figure 2.5 List of Vegetable Fibers

2.2.3.2 Animal (Protein)

It is possible to get naturally occurring fibers derived from animals, known as animal fibers. Several proteins combine to form these fibers. Silk and wool are two of the most common animal fibers, as seen in Figure 2.6. Bearing in view that animal fibers from different animals have different characteristics is essential. Various species may also utilize different types of fibers (McGregor, 2018). The most prevalent textile fibers derived from animals are animal fibers. A variety of animal fluids and hairs as well as skin and fur are routinely utilized to create these fibers (insects like as silkworms are to contribute).

Figure 2.6 List of Animal Fibers

Animal fibers are generally woven or knitted (or sometimes felted) into gorgeous animal textiles once they have been removed. Animal fibers have traditionally been used to make comfortable jackets, wraps, blazers, shawls, ponchos, coats, and other garments and accessories. Typically, rougher animal fibers are used in carpets, coverings, and rugs. Wool kinds such as Cotswold and Merino, for example, are distinct (derived from several sheep species). The former is distinguished by its coarse texture, whereas the latter is distinguished by its soft texture. It's also worth noting that nature fibers vary in consistency, whereas synthetic fibers are more consistent.

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2.2.3.3 Mineral Fibers

Although it is a natural sources fiber, it can also be a mineral-derived fiber that has been somewhat changed. Asbestos, ceramic fiber, and metal fiber are the three types of mineral fiber available. Asbestos, like serpentine, amphiboles, and anthophyllite, is the only naturally occurring mineral fiber. Glass fiber, aluminum oxide, silicon carbide, and boron carbide are examples of ceramic fibers. Glass fibers include quartz and glass wood. The metal fiber family includes aluminum fiber as one of its members (Britannica, 2020). The types of mineral fibers can be more define as illustrated in Figure 2.7.

Figure 2.7 List of Mineral Fibers

Mineral fiber products are typically created in three steps: (1) raw material fusion, (2) fiber production, and (3) fiber conversion to a commercial product. The fusion (melting and mixing) of raw materials in a furnace is the first step. Raw materials are chosen to provide the finished product the desired qualities. The liquid is pulled from the furnace to create a preform that will be remelted at a later time, or it goes straight to a fiber-producing unit. Fiber formation is the second step. Directing a jet of hot gas at a liquid stream or centrifugal attenuation are both used to make fibers. Filaments are drawn (extruded) fibers that are pulled through nozzles. Chemical treatment and the production of blankets, mats, yarns, fabric, moulded forms, and other product kinds are used to turn fibers into commercial items in third step.

2.3 Composite Material

A common composite material is formed by two or more elements on a microscopic level (mixed and bonded). Cement, sand, stone, and water are the main ingredients of concrete, for example. If the composition occurs on a microscopic scale, the new material is referred to as an alloy for metals or a polymer for plastics (molecular level).

As seen in Figure 2.8, composite materials are composed of reinforcement (fibers, flakes, and/or fillers) inserted in a matrix (polymers, metals, or ceramics). The reinforcement helps to maintain the matrix in alignment while also improving the mechanical properties of the matrix. Composite materials, when correctly constructed, are stronger than the sum of their parts (Reddy Nagavally,2017).

Figure 2.8 Fiber-Reinforced Polymer (Polyester) composites

Most of our industry's products use polyester resin as the matrix and synthetic fibers as the reinforcing. Composite products on the other hand are made from a wide range of materials that all work together to create something special. Resilient resin, on the other hand, protects and shapes the fibre, making it more durable. Fiber-reinforced polymer(polyester)

composites may benefit from the addition of fillers, additives, core materials, and outer layer finishes to the manufacturing process, design, and performance of the finished product.

2.3.1 Types of Composites Materials

Composite materials are often divided into the two tiers listed below. The first level of categorization is usually classified using the matrix component. Ceramic matrix composites, Metal matrix composites, and Organic Matrix Composites (OMCs) make up the three primary categories of composites (CMCs). It is common to use the term "organic matrix composite" (OMC) to refer to both polymer matrix composites (PMCs) and carbon matrix composites (CMCs) (Machado & Knapic, 2017).

Composites that include fibers, laminar composites, and particles as reinforcing materials are categorized as second-level composites. Continuous and discontinuous fiber-reinforced composite materials (FRP) may be divided into two categories. Fiber Reinforced Composites are composed up of fibers put into a matrix. Fiber length may have an effect on the properties of a material, which is known as a discontinuous fiber or short fiber composite. Continuous fiber reinforced composites are those in which the fiber length is such that an increment in the composite's elastic modulus has no effect. Despite their small diameter and fast axial bending, fibers offer exceptional tensile properties. To prevent fibers from buckling and bending, they must be stabilized.

In laminar composites, the layers are held together by a matrix. Sandwich constructions are included in this category. In a matrix, particles are spread or embedded to form a Particulate Composite. Powder or flakes are possible particle shapes. Concrete and wood matrix composites are examples of this kind of material. Based on the type of reinforcement, most composite materials may indeed be classified as shown in Table 2.1.

Table 2.1 Common form of reinforced composite materials (Reddy Nagavally, 2017)

2.3.2 Structural Composites

The characteristics of the component materials, as well as the geometrical design of the various structural elements, define the quality of a structural composite, which is typically composed of the both homogeneous and composite materials. Among structural composites, sandwich sheet panels and laminated composites are some of the most commonly used.

2.3.2.1 Laminar Composites

Laminar composites are two-dimensional sheets having a necessary for high orientation, such as wood and fibre reinforced plastics. Figure 2.9 shows how the layers are stacked and bonded such that the high-strength directional movement with each layer. The grain direction of adjacent plywood sheets is perpendicular to each other (Gholampour & Ozbakkaloglu, 2020). Laminations may be made from cotton, paper, or woven glass fibres in a plastic matrix. In two dimensions, a laminar composite possesses great strength in many directions, but the strength in any single axis is lower compared if all the fibres were oriented in that direction.

Figure 2.9 Laminar composite of fiber reinforced layers
2.3.2.2 Sandwich Sheet Panels

Structural composites, such as sandwich sheet panels, are lightweight beams or boards with a high level of stiffness and strength. In Figure 2.10, a sandwich sheet panels consists of a thicker core sandwiched between two thinner outside sheets, or faces. Aluminum alloys, fiber-reinforced plastics, titanium, steel, or plywood are common materials for the external sheets. Stiffness and strength are provided by the structure's ribs, which must be thick enough to sustain the pressures of loading. The core material is generally made of a thin, light material with a low elastic modulus. The three most frequent core materials are rigid polymeric foams, wood, and honeycombs (Alsubari et al., 2021).



Several structural functions are served by the core. First of all, it offers constant support for the face. Transverse shear forces and a high shear stiffness must also be supported by its strength and thickness (to resist buckling of the panel). In terms of tensile and compressive loads, the core is significantly less affected than the faces.

2.3.3 Matrices for general composites

Matrix materials for composites include ceramics, metals, and polymers (polyesters), as shown in Figure 2.11. Such matrices are used in a number of ways in the composite construction. In addition to providing the necessary stability, they may feed fibres in a desired shape, separate and protect the fibers from the outside environment, and lastly convey stress to the fibers themselves (Zafeiropoulos, 2008). Their physical and mechanical characteristics vary in the following ways.



Figure 2.11 Classification of matrices for general composites

2.3.3.1 Ceramic matrices

They are regarded as the best matrices in terms of mechanical and thermal qualities. Since they are tough to work with, it is difficult to transfer the fibers evenly within the matrix, and it is difficult to remove internal porosity, they are no longer often used in the construction industry. Aluminum oxides (Al2O3) and Silicon oxide (SiO2) are the two most often utilized ceramic matrices today.

2.3.3.2 Metal matrices

When it comes to quality and affordability, metal matrices sit somewhere in the middle between ceramic and plastic matrices. Temperature limits are depending on the metal that composes the matrix, however they are greater than the temperatures of metal alone under the same circumstances. Aluminum alloys are the most widely utilized metals, whereas composite composed on titanium, magnesium, nickel, and copper are typically employed when working circumstances need a larger temperature range. Metal matrices are constrained by the possibility of chemical reactions between the matrix and the fibers (Varghese & Mittal, 2017). For this reason, it has a shorter anticipated lifespan.

2.3.3.3 Plastic (polymers) matrices

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Composites are composed of two main families of plastic matrix, each with its unique set of performance and attributes. This dispersion of features is caused by the distribution pattern of distinct module types and the degree of crystallinity. Thermosetting is the first of these families. When heated, they may be made stronger, but if the temperature is exceeded, they will be annihilated. After polymerization, they cannot be remoulded, heated, or returned to their former state. Compared to other plastics, thermos matrix is the best choice for hightemperature applications (thermoplastics). The most popular thermosetting polymers include polyester, phenolic, silicone, and epoxy (resins).

It is possible to melt thermoplastics as the second family, but after they cool, they retain their properties and may be moulded, remelted, and heat treated even after they have polymerized. Some thermoplastic uses, which are used to swiftly and efficiently build complex component shapes, are restricted by low temperatures. It is possible to melt and form these matrices by heating them up, with no chemical reactions taking place during the process of solidification. A number of processes, including as injection or extrusion, may be used to forge it into any predetermined form. These polymers are melted and inserted into the mould, and since they're in contact with the mold's walls, they will harden over time. Table 2.2 provides a summary of the most important properties of several polymeric matrices.

Resins	Туре	Density (g/cm^3)	Young's modulus (N/mm^2)	Tensile strength (N/mm^2)
Ероху	Thermosetting	1.1-1.4	2100-5500	40-85
Polyester	Thermosetting	1.1-1.4	1300-4100	40-85
Phenol formaldehyde	Thermosetting	1.2-1.4	2700-4100	35-60
Nylon	Thermoplastic	1.1	1300-3500	55-90
Acetal	Thermoplastic	1,4	3500	70
Polyethylene	Thermoplastic	0.9-1.0	700-1400	20-35
Polycarbonate	Thermoplastic	1.2	2100-3500	55-70

Table 2.2 Characteristics of some plastic matrices (AL-Oqla and Salit, 2017)

2.4 Honeycomb

Honeycombs and honeycomb materials are used to make sandwich sheet panels with a honeycomb core that has a high compressive strength. With using core materials such as paper, thermoplastics, or fabric, honeycomb structures may be created even if the building components themselves are brittle.

Constructions made of honeycomb resemble genuine beehives in design. There is a layer of hollow cells between thin vertical walls in all of these formations, as seen in Figure 2.12. Most of the cells are hexagonal or arranged in rows. Honeycombs are often used in flat or slightly curved surface applications because of their high specific strength (Alsubari et al., 2021). One of the primary reasons for its extensive usage in a variety of sectors, including packaging, furniture, automobiles, and sporting goods, is their long-term resilience.



Figure 2.12 Structure of Honeycomb Sandwich Composite

Honeycomb has been used in man-made structures since the classical era. It was Euclid and Zenodorus, ancient Greek mathematicians, who established that hexagonal patterns were the most efficient and long-lasting. The Pantheon dome in Rome, which would be an early example, incorporated honeycomb elements in the interior structural ribbing. In 1638, Galileo sparked a discussion over the structural integrity of hollow things. As according Charles Darwin in 1859, honeycomb shapes are ideal for reducing the amount of work and wax required. When honeycomb structures were first invented in 1901, three fundamental methods of production were devised for expanding, corrugating, and moulding.

2.4.1 Types of Honeycombs

There are a variety of materials that may be used to make honeycomb cores. These include materials like paper and cardboard, which are utilized to offer a lower strength and stiffness in low-load applications, to greater strength and stiffness for increased performance applications, such as airplane structures. Honeycombs may be used to create flat or curved composite structures. Intricate compound curving shapes may be created without the use of substantial mechanical force or heat.

Thermoplastic honeycomb cores are produced by extrusion and then sliced to desired thicknesses. Some honeycombs, like those made of paper or metal, must undergo a lengthy production process before they are ready for market. These processes include printing large, thin sheet panel of the material and stacking them in a hot press in order to improve adhesive bonding. Stretching and extending these slices results in continuous sheets of hexagonal cell shapes. The qualities of honeycomb materials are determined by the cell size, and even the thicknesses and strength of the material used (He & Hu, 2008).

2.4.1.1 Aluminium Honeycombs

The strength-to-weight ratio of these honeycombs is unrivalled by any other structural material. They have a variety of geometric cell forms and qualities that are influenced by the thickness of the foil and the size of the cells. The resultant honeycomb is stretched to produce a sheet from an unexpanded block. If used in specific situations, such as maritime

constructions, aluminium honeycombs (Figure 2.13) may corrode. When a honeycomb is struck by a cored laminate, it deforms irreversibly.



Figure 2.13 Aluminium Honeycomb

2.4.1.2 Nomex Honeycombs

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Nomex honeycombs (Figure 2.14) are made of Nomex paper, which is a form of Kevlarbased paper. These honeycomb cores are utilized in aircraft interior panels and other highperformance components because they combine great strength with fire resistance. Although they are more expensive than other materials, they are favored because to their low density, solid stability, and mechanical strength.



Figure 2.14 Nomex Honeycomb

2.4.1.3 Thermoplastic Honeycombs

Thermoplastic honeycomb cores are both light and recyclable because of their honeycomb structure. There is a major drawback to honeycombs since they are difficult to adhere to skin. They are available in a variety of forms, the first of which is ABS, which provides rigidity, toughness, surface hardness, impact resistance, and dimensional stability. Polycarbonate is the next kind, which has UV stability, high light transmission, high heat resistance, and self-extinguishing qualities. Aside from that, polypropylene has a high chemical resistance. Polyethylene, an affordable general-purpose core material, is the last form of thermoplastic honeycomb (Figure 2.15).



Figure 2.15 Thermoplastic Honeycomb

2.4.1.4 Stainless Steel Honeycombs

Joiner panels, bulkheads, train doors, and flooring, as well as any other areas where honeycomb is exposed to harsh environments, could all benefit from stainless steel honeycomb (Figure 2.16) cores.



Figure 2.16 Stainless Steel Honeycomb

2.4.2 Mechanical Properties of Honeycomb Structures

The mechanical properties of honeycomb structures are orthotropic, which indicates that their values vary depending on the direction of stress applied to the material. Consequently, the two symmetry planes should be identified and separated. For example, the L-direction (which is strongest) is located 60 ° from the W-direction (which is most compliant) in standard hexagonal honeycomb (Qiao & Davalos, 2013).

Honeycomb materials are made through one of the three standard methods. Expansion, corrugation, and molding are the methods used. Expansion and corrugation are being used to make composite honeycomb materials. Honeycomb materials made of metal (typically aluminum) are created purely through the expansion process. Thermoplastic honeycomb materials, on the other hand, are often made by extrusion methods and then cut into honeycomb sheets.

2.5 Materials Selection

The material selection, which is a critical element in the engineering design process, begins with the selection of materials. It is critical for a draughtsman to select the suitable materials for a design they have made in order for the product to perform its duties as efficiently as feasible. Today, there is an ever-increasing variety of materials available, each with its own set of features, applications, advantages, and disadvantages.

Each component's functional needs must be well understood, as well as many other critical criteria or aspects, when it comes to the selection of materials for engineering designs. "Material selection factor" is a term that refers to any element that determines the selection of a particular material for a certain purpose. Cost, shape, material environmental impact, performance features, availability and so on are only a few of these factors (Sapuan, 2017).



Figure 2.17 Knowledge required for materials selection

There are several factors to consider while selecting materials, as depicted in Figure 2.17. Each of these areas has a significant impact on the selection of materials. When it comes to choosing the right material, it's important to consider a wide range of factors such as physical characteristics (such as machinability and formability, weldability and castability), electrical characteristics (such as magnetic properties), mechanical characteristics (such as heat treatability) and chemical characteristics (ANON, 1971). As a result, the selection material should be examined very carefully to ensure that the project is capable of its full potential.

2.6 Materials and Methods for Nature Fiber Composites

2.6.1 Material Preparation

Materials used in this experiment were banana, pineapple, sisal, and glass fibre, according to (Idicula et al., 2006). Unsaturated isopthalic polyester HSR 8131 served as the matrix. Table 2.3 provides an overview of polyester resins most important characteristics. Commercial grade compounds included PSMA, sodium hydroxide, cobalt napthenate, and methyl ethyl ketone peroxide.

Surfacing	Clear pale- yellow liquid
At 25 degrees Celsius, the viscosity (cps) Specific Brookefield viscometer	650.0
At 25 degrees Celsius, the specific gravity is	1.110
After curing for 24 hours at room temperature, sp post-cured for four hours at 80 degrees Celsius fo characteristics.	ecimens were then r unreinforced resin
Testing of tensile strength	33 MPa
Testing of tensile strength Testing of flexural strength	33 MPa 70 MPa

Table 2.3 Characteristics of liquid resin

2.6.1.1 PSMA treatment

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It took half an hour for the chopped fibers to dissolve in a 5 percent PSMA in toluene solution containing toluene that had been refluxed. Afterwards, the fiber was purified and baked at 70 degrees Celsius until it was completely dehydrated.

2.6.1.2 NaOH treatment

To remove any alkali particles, the cut fibers were treated for an hour with a 10% sodium hydroxide solution before even being washed with a very mild acid. Once the alkali had been removed, the washing procedure was repeated. A 70-degree Celsius oven was used to dry the cleansed fibers.

2.6.1.3 Preparation of composites

Using a 150 x 150 x 2.5 mm mould, each piece of banana and sisal fiber was evenly distributed and cut into 30mm pieces. Cobalt naphthenate and peroxide were used to make the composite sheets by impregnating the fiber with polyester resin having 1% cobalt naphthenate and 1% MEK peroxide. With a roller, air bubbles being carefully eliminated from the resin before to pouring. Specimens were post-cured at 30 degrees Celsius for 48 hours before being cut into desired-size test specimens using a pressurized closed mould.

Different fibre volume fractions were used in the manufacture of the samples. Two more composites were constructed using PSMA and sodium hydroxide-treated fibre with a constant volume percentage (0.40 Vf). As previously stated, PALF and glass fibre composites were made. Several hybrid composites were made by varying the volume percentages of PALF and glass. The fibre loading for all PALF/glass fibre composites was maintained at 0.40 Vf.

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2.6.2 Testing method

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2.6.2.1 Thermal measurements (Experimental set-up)

The thermal efficiency, diffusivity, and thermal capacity of polymer composite materials were measured at room temperature using a monthly approach as shown in Figure 2.18. This technique employs a little temperature variation in a parallelepiped-shaped sample (44 mm \times 44 mm \times 2.5 mm) to collect all of these thermophysical parameters in a single measurement, together with their statistical confidence bounds. The sample is held in place between two metallic surfaces. The use of conductive grease provides a proper heat exchange between the various plates and the sample. The front and back metallic plates have

thermocouples placed to measure the temperature, and a total of five sinusoidal impulses are used to heat the front side of the first metallic plate on a regular basis.



Figure 2.18 Thermophysical measurements set up

By comparing actual and theoretical heat transfer functions, the thermophysical characteristics of the sample are determined. One-dimensional quadrupoles theory is used to model the system under investigation. At each excitation frequency, the experimental heat transfer function H is determined as the ratio of the front and rear plates' Fourier-transform temperatures. Thermodynamic conductivity (k) and diffusivity (a) are then estimated concurrently using a parameter estimation approach.

For the thermophysical parameters identification, the Levenberg-Marquardt method of nonlinear optimization is used, starting with reasonably good baseline predictions for the uncertain variables. These findings and associated uncertainties are shown in Table 4 for composites constructed with chemically treated fibers, as well as the results of thermophysical experiments.

	k (W m^-1	a (m^2 s^-1)	Cp (J kg^-1	ρ (kg m^-3)
	K^-1)	· 10^-7	K^-1)	
Polyester only	0.181 ± 0.003	1.08 ± 0.09	1408 ± 123	1190± 123
Polyester + 0.20 Vf	0.153 ± 0.002	1.25 ± 0.09	1199 ± 88	1021 ± 88
Polyester + 0.40 Vf	0.140 ± 0.002	1.14 ± 0.09	1246 ± 103	986 ± 103
Polyester + 0.40 Vf treated	0.201 ± 0.003	1.37±0.10	1270 ± 98	1155 ± 98
with NaOH UNIVERSIT	TEKNIKAL	MALAYSIA	MELAKA	
Polyester + 0.40 Vf treated	0.213 ± 0.002	1.43 ± 0.25	11 94 ± 120	1248 ± 77
with PSMA				

Table 2.4 The thermal conductivity, thermal diffusivity, specific heat, and density of banana/sisal composites (Idicula *et al.*, 2006)

2.7 Design of Honeycomb Structure using ANSYS Analysis

2.7.1 Experimental Aspects

2.7.1.1 Design Procedure

The initial step in the design process is to develop the hexagonal cell structure and then extrude it. This needs the use of basic tools. An assessment group of hexagonal cells will just be constructed after that. On the second tier, you'll find the rectangular paneling style of panels. Finite difference and finite element techniques are used to simulate physical processes in 1D, 2D, and 3D models (internal ballistics, fluid dynamics, continuum mechanics structural analysis). All the way to the final geometry specification, they allow precise calculations or optimization.

2.7.1.2 Problem Definition

A professional must identify structural loads, dimensions, support conditions, and material characteristics in order to execute an appropriate analysis. Deformation, strains, and displacements are common outcomes of such an evaluation. After then, the data is evaluated to indicators that indicate failure circumstances.

2.7.1.3 Material selection

Various materials have been chosen from the instruction for the provided attributes of materials, such as Aluminium.

2.7.1.4 Design Phase

Dassault Systems' CATIA (Computer Aided Three-dimensional Interactive Application) is a multi-platform CAD/CAE/CAM commercial software suite. It is a highly useful tool for modelling and drawing. Innovative designers must have access to technologies that allows them to construct and change the emotional content of a product through their designs. CATIA is extremely useful for product modelling and drawing. It comprises more than 60 segments that range from easy aketching through component design, drawing, sheet metal design, 2D and 3D design, and design (Nazeer, 2015). Features that are beneficial at certain periods are dependent on requirements, derived through the usage of generative form design the tool's evaluation.

2.7.2 Modelling

This tool can create hexagonal cell structures that are incredibly tiny in size, depth, length, and thickness. There are four steps in modelling process of honeycomb sandwich consists (a) modelling in the Catia software, (b) modelling of hexagonal cell, (c) assembly of hexagonal cells and lastly, (d) modelling of panel as illustrated in Figure 2.19.



Figure 2.19 Modelling process of Honeycomb sandwich: (a) Hexagonal Cell Structure (b) Hexagonal cell extrude (c) Assembly of Hexagonal Cell (d) Rectangle plate (H D and L, 2016)

2.7.3 Ansys Analysis

Professionals use Ansys software for simulation modelling (computer-aided engineering). It was founded by Dr. John A. Swanson in 1970 as Swanson Analysis Systems Inc. (SASI). Create and market finite element analysis software for structural physics that could analyse static, dynamic, and thermal concerns. To solve a broad variety of mechanical problems numerically, Ansys is a finite-element modelling tool. Finite-element modelling has three steps in theory. As a first step, pre-processing is used to identify potential issues. Next, we'll talk about how to solve the problem by spreading out the work, setting boundaries, and finally finding a solution. Finally, post-processing may be required for further processing and review of the results.

2.7.3.1 Honeycomb structural analysis

As a part of the structural analysis, we will look at deflection rates in terms of stress and strain (Von Mises's). As seen in the experiment in Figure 2.20, pressure has been applied to one side while maintaining the DOF on the other side at zero. Consequently, aluminium deformation, Von Misses stresses, and aluminium strains have been discovered as well as the stress and strain, together with the component's strength, being tested to determine what it can do. This is a step-by-step guide to doing an aluminium structural analysis, as illustrated in Figures 2.21, 2.22, and 2.23. As a result of this experiment, Table 2.5 now contains the aluminium deflection, stress, and strain data.



Figure 2.20 Applying pressure on the panel while maintaining the opposite side's DOF at zero



Figure 2.21 Aluminium's deformation



Figure 2.22 Aluminium's Von Misses stress



Figure 2.23 Aluminium's Von Misses strain

 Table 2.5
 The values of deflections, stress and strain (Nazeer, 2015)

	Aluminium
Deflection (m)	0.118E-05
Stress (N/m^2)	0.569E+07
Strain	0.813E-04

2.7.4 Thermal Analysis

In a system or component, a thermal analysis determines the temperature distribution and related thermal quantities. Temperature distributions, heat loss or gain, thermal gradients, and thermal fluxes are all common thermal parameters of relevance.

Many technical applications, such as internal combustion engines, generators, heat exchangers, pipeline systems, and electronic components, rely heavily on numerical modelling. To compute thermal stresses, engineers frequently combine a numerical simulation with a stress analysis which is, stresses due to high or low temperature. Thermal studies are only supported by the Ansys software Multiphysics, Ansys software Mechanical, Ansys software Professional, and Ansys software FLOTRAN (mechanicalland, 2022). A heat balance equation derived from the concept of conservation of energy serves as the foundation for thermal analysis in Ansys software. The nodal temperatures are calculated by the finite element analysis that conduct using Mechanical APDL, and the nodal temperatures are then used to determine additional thermal values. Conduction, convection, and radiation are the three basic mechanisms of heat transport handled by the Ansys software.

2.7.4.1 Transient Thermal Analysis

Transient thermal analysis is supported by the Ansys software platforms as mentioned in previous topic. Thermal parameters that change over time are determined via transient thermal analysis. Professionals frequently utilize the temperatures calculated by a transient thermal analysis as input to structural calculations to determine thermal stress. Transient thermal assessments are used in many heat transfer applications, such as heat treatment difficulties, nozzles, engine parts, piping systems, and so on. The processes for a transient thermal analysis are similar to those for a steady-state thermal study.

2.7.4.2 Honeycomb thermal analysis

At 100°C, an aluminium honeycomb sandwich construction transmits heat away from one panel and converts it to a surrounding fluid at 25°C. The heat transmission coefficient for convection is 10 w/ m2.k. The thermal conductivity (k) of copper is 310 W/m K and 910 J/kg K is specific heat (Cp). For the density is 2699 kg/m3 (Nazeer, 2015).

For the transient study, a 25°C beginning temperature for the structure will be used. Heat would begin to flow from the panel into core honeycomb cells at time t=0, where some of it will be stored (thus the need for specific heat and volume) and some will be transported away. The temperature distribution in the fin would become stable over a period of time. Transient solutions require a different solution for each time step, but steady state solutions only require the system of equations characterizing the model to be solved once.

Based on the starting circumstances, Ansys software will calculate the temperature distribution at t=10 s. The temperature distribution at t=20 s will be determined by Ansys software based just on temperature distribution at t=10 s, and so on. The precision of the solution is determined by the size of the time increments as well as mesh properties. The transient solution has been shown in Figure 2.24 and 2.25 below meanwhile, the values for time and temperature for aluminium as illustrated in Table 2.6.







 Table 2.6
 Transient solution values for aluminium

Time	10	20	30	40	50	60	70	80	90
Temperature	87.02	93.45	95,33	95.98	96.21	96.29	96.32	96.32	96,33

2.8 Thermal Analysis of Nature Fiber Reinforced Polymer Composites

2.8.1 Methods Used to Determine the Thermal Properties

Many methods are used to evaluate the thermal properties of nature fiber composites and to determine which fiber-reinforced composites are best suited for a certain application. Methodologies used in the literature review for thermal studies of composites include TGA, DSC, and DMA (Neto et al., 2021). Fig. 2.26 gives a summary of the most often used techniques for assessing the thermal properties of composite materials, and the essential thermal characteristics that these approaches yield. Thermal characterization methods for nature fiber composites are discussed in this section.



Figure 2.26 The principal method used to determine thermal properties of composites

2.8.1.1 Thermogravimetric Analysis (TGA)

A material sample's weight may be measured as a function of temperature or time using TGA analysis in a controlled setting such as nitrogen, helium, air, or other gases. Temperatures and measurement times vary depending on the nature fiber reinforced sample's matrix type. Moisture, volatile chemicals, loss on igniting, and ash are all frequent thermogravimetric properties. Thermal data obtained from TGA analysis is affected by the sample mass and shape, the environment, the flow velocity, the temperature rate, and the treatment conducted. Table 2.7 summarizes the results of numerous recent studies on the thermal properties of nature fiber composites.

Fiber	Matrix	Thermal Properties The addition of bamboo fiber did not result in a significant improvement in the composites' first onset degradation temperature (T onset).		
Bamboo	Polyester, Epoxy and Vinyl ester			
Curauá	Polyester	The inclusion of fibre and the chemical treatment of fibres with NaOH increased the composites' thermal stability.		
Buriti and ramie	Polyester	The ramie fiber reinforced composite's greatest peak degradation temperature (Td) was 372°C, whereas the buriti composites was 346°C.		
Sisal and UNIVE kena	Polyester NIKA	When compared to neat fibre composites, hybrid composites have better thermal stability.		
Jute, jute + sisal and jute + curauá	Polyester and Epoxy	When compared to polyester composites, T onset was greater for jute, jute + curauá epoxy composites. For both matrices, there was no significant difference in T onset for jute + sisal.		
Mulberry	Polyester	The thermal stability of the composites improved when the NaOH content was raised.		

Table 2.7 Thermal properties of nature fiber composites obtained from TGA analysis

2.8.1.2 Differential Scanning Calorimetry (DSC)

In terms of temperature and time, the DSC can indicate when a material is transitioning between two states. By comparing the magnitudes of the endothermic (heat absorbed) and exothermic (heat released) peaks, it is possible to determine the thermal phase shift of composites. The key thermal parameters established from this study are the glass-transition temperature (Tg), crystallisation degree (Xc), crystallisation temperature (Tc), and fusion temperature (Tm). It is also possible to compute the composite's enthalpy fluctuation and heat capacity. Tg is an important material feature to consider when choosing natural composites for a certain end-use application. Thermal set polymer Tg refers to the temperature range when a polymer transforms from a rigid to a more flexible or rubbery state as is well-known, the "normal" state of most thermoset polymers at room temperature is a rigid one (amorphous solid). thermoset resins' molecular chains do not have enough kinetic energy to move freely below their Tg.

Another thing that happens is that the polymer resin molecules become more active when they are heated. Polymer molecules may freely move around one another when the rubbery state of thermoset polymer resin is attained by heating it to a specified quantity of energy. The temperature at which this transformation happens is known as the glass transition temperature. To summarise, the temperature of polymer resin should never exceed Tg during service. Although their mechanical properties (strength and stiffness) will quickly decline if the composites are used above their Tg, certain mechanical capabilities will be kept until the temperature surpasses the Tm. It is the temperature at which polymer chains may be aligned in a different way. Lamellac, will be found which are organised crystalline chain areas, as approach the Te. However, amorphous regions remain throughout the structure. Te is hotter than Tg, but not hot enough to melt it (Tm). Last but not least, polymeric chains break their bonds and turn into liquids at a temperature known as the melting temperature (Tm). This is known as an endothermic transition. Thermoset polymers often have a higher Tm than Tg. At temperatures over Tg but below Tm, the polymer resin becomes rubbery, and it may deform significantly under very mild force. The sample size and shape, the heat ramp, and the environment in which the DSC investigation is conducted all have an influence on the outcomes. Several recent DSC-based studies on the thermal properties of natural fibre composites are summarised in Table 2.8 (below).

Fiber	Matrix	Thermal Properties
Curauá	Polyester	The Tg of the composites was raised as a result of the chemical treatments. Ca (OH)2 was the most effective treatment, with a Tg of 141.92 C.
Jute + ZrO2	Polyester	The addition of nanofiller boosted the composite's Tg.

Table 2.8 Thermal properties of nature composites obtained from DSC analysis

2.8.1.3 Dynamic Mechanical Analysis (DMA)

For example, DMA may be used to calculate the storage modulus (E'), loss modulus (E''), damping factor (tan = E^{u}/E') and the glass transition temperature (Tg). The elastic characteristics of the material's storage modulus (E') are linked to energy storage. When heated, the "stiffness" of the composites sample is reduced. It is the viscous component of the composite sample that helps dissipate energy, which is linked to the loss modulus (E). Molecular dissipation and internal molecular friction are interconnected because of morphological transitions and relaxation, morphology, and system heterogeneity.

Tan = $E^{"}/E"$ is used to determine a damping factor, which is related to the internal mobility of polymeric chains and demonstrates the influence of fiber/matrix interactions. tan = E"/E"This indicates that the polymeric chain is more prone to movement, but a low value in the ratio indicates that the fiber/matrix interfacial connection is strong, implying that the system wastes less energy than it is storing. DMA measurements of the complex modulus are typically used to calculate Tg, and the temperature increases at a constant rate.

In the DMA analysis, there are a variety of test combinations to choose from (for example, dual cantilever, single cantilever, three-point bending, torsion, shear, tension, and compression). As opposed to single and double cantilever modes, which provide mixed loading, the three-point bending mode produces measurable stresses in relatively rigid materials, making it the most preferred test procedure for composite materials. DMA analysis may record significant (up to 25°C) variation in the glass transition temperature for a specific material, depending on the technique used.

Nature fiber composites gathered by DMA have unique thermal properties based on their physical or structural arrangement of phases (interface), form, and natural composite constituents. A composite material's dynamic mechanical properties may be influenced by the presence of fillers, fiber content and orientation, and chemical treatment of the fibers. The results of the DMA test are also affected by the testing procedure. Various recent studies have used DMA analysis to investigate the thermal properties of nature fiber composites, as shown in Table 2.9.

Fiber	Matrix	Thermal Properties		
Mulberry	Polyester	The storage modulus (E') of the composite was raised by 10% after treatment with NaOH. The fibres lowered the Tg (the plain resin had a Tg of 69 °C, whereas the untreated composites had a Tg of 63 °C).		
Ramie + Buriti	Polyester	In comparison to the other treated instances, the ramie reinforced composite treated with 2% de NaOH had a greater storage modulus and loss modulus.		



2.8.2 Finite Element Modelling

The microstructure and micro distribution of natural fibre have a significant impact on the thermal characteristics of Nature Fiber Reinforced Polymer Composites (NFRPC). Researchers in traditional finite element modelling thought that the structure was homogenous and did not take into account the microstructure of natural fibre. Natural fibres, on the other hand, have a solid area and a lumen in their microstructure, which has a significant impact on the thermal characteristics of NFRPC. A 2-dimensional RVE model was built to solve this problem (Naveen *et al.*, 2018). The NFRPC's 2D model is shown in Figure 2.27. In the FEA, the effective thermal conductivity of NFRPC may be determined using the following formula:



which is k being the effective thermal conductivity, t1 and t0 are the temperatures at the borders, q is the heat flow, and L is the side wall length.



Figure 2.27 2-dimensional model of the NFRPC

2.9 Conclusion

In conclusion, this chapter has provided a lot of information based on previous studies related to the topic of research, simulation and application of Nature Fiber/Polyester Aluminum honeycomb for Thermal Analysis for Malaysian Shelter Application. Information based on previous studies consists on nature fiber and polyester, composite material, honeycomb, material selection, materials and methods such as modelling and assembly through SOLIDWORKS and ANSYS, and lastly thermal analysis of nature fiber reinforced polymer composites. Thermal analysis section also contains the equation in determine thermal conductivity nature fiber reinforced polymer composites. Furthermore, theories that have been found in the literature review regarding to the research absolutely helping in report for the next chapter. Last but not least, the combination of nature fiber composite with aluminium honeycomb sandwich becomes the first choice for the research as meets all criteria in various aspects especially in material properties of material conductivity.

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CHAPTER 3

METHODOLOGY

3.1 Introduction

The aim of this study is to come up with the ideal to develop 3D sandwich model of thinwalled honeycomb with nature fiber composite in order to find their behaviors of thermal analysis for Malaysian Shelter Application. This study focuses on the process of material preparation that consists modelling 3D design using SOLIDWORKS and evaluate the thermal analysis of the model in terms of thermal conductivity using ANSYS. Material properties of varied nature fiber and aluminium sandwich panel should be considered before starting the experiment. Figure 3.1 shows the complete processes that were followed in order

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to complete the study.



Figure 3.1 Flow chart of methodology process

3.2 Material Selection

The phrase material selection factor refers to any factor that influences the choice of material for a certain application. In order to accomplish the experiment, aluminium honeycomb sandwich as a core with the panel sheet (upper and lower) reinforced by nature fiber composite as adhesives were selected before modelling design using Solidworks software and imported the model into Ansys software for thermal analysis using steady-state thermal. Furthermore, material properties of aluminium for honeycomb along panel sheet of varied nature fiber composite need to evaluated and it is important to determine appropriate materials for the experiment so it is giving the right outcomes at the end.

3.2.1 Hexagonal cell structure honeycomb

Honeycomb structure is created by a space filling technique or higher-dimensional cells where there is no gap between two cells. In any number of dimensions, it is an instance of the more general mathematical slating or tessellation. Honeycombs can be constructed in Euclidean ("flat") space as well as non-Euclidean spaces (Al-Azad, Dedifitrianto and Shah, 2021). In spherical space, every finite uniform polytope may be translated to its circumstance to produce a uniform honeycomb. Using Solidworks software, hexagonal cell structures as shown in Figure 3.2 that are quite tiny in size, depth, length, and thickness can be designed.



Figure 3.2 Hexagonal cell structure honeycomb 51

3.2.2 Varied nature fiber

Nature fibers are those that may be obtained and removed readily from vegetable (cellulose), animals and mineral source. Natural fibers are more beneficial and long-lasting than synthetic fibers, which has led to their use in a wide range of industries. Regarding to the experiments, selected varied nature fibers are sugarcane, coconut and palm oil as illustrated in Figure 3.3.



(c)

Figure 3.3 Varied nature fiber: (a) Sugarcane (b) Coconut (c) Palm Oil

3.3 Material properties

It is important to define the material properties that were selected in order to accomplish the expected results of the experiment. Regarding to the Table 3.1 below, the material properties in terms mechanical properties especially thermal conductivity of varied nature fiber composite has been displayed.

 Table 3.1
 Thermal conductivity of varied nature fiber composite (Aaksh koli, 2015)

Fiber	Thermal Conductivity (W/mK)				
Fraction (%)	Coconut	Sugarcane	Palm Oil		
0 wt.%	0.357	0.363	0.361		
2 wt.%	0.184	0.255	0.232		
4 wt.%	0.162	0.237	0.211		
6 wt.%	0.143	رسيتي 0.219	0.195		
8 wt.%	RSITI TEKNIKAL 0.125	0.194	0.174		
3.4 Material preparation

Material preparation in the experiment consists modelling 3D sandwich model of thin-walled honeycomb with nature fiber composite as shown in Figure 3.4 using Solidworks software. After that, the 3D model has exported into Ansys software in order to evaluate the material properties testing of nature fiber composite honeycomb sandwich especially in thermal conductivity.



Figure 3.4 Honeycomb sandwich with varied nature fiber composite: (a) Sugarcane Composite (b) Coconut Composite (c) Palm Oil Composite

3.4.1 Modelling and assembly

Multiple layers of thin sheets of metallic (or nonmetallic) plates are linked together and suitably bent to create the honeycomb-core structure. The tiny strips are initially joined together in parallel zones that are evenly spaced. The joining regions over one part of each thin sheets is staggered in relation to the bonding zones on the opposing side. Through folding of the bonded and free junctures, the bonded multiple sheet structure is subsequently pushed apart in the thickness direction to generate a finalized honeycomb structure. A variety of varied honeycomb cell shapes might be produced by varying the width and spacing of the composite structure belt zones, as well as pulling apart the many layers by bending displacements to a desired result.

The Figure 3.5 depicts the sort of honeycomb hexagonal cell that have been modelled using Solidworks software. In order to make the pattern easier, just measure the distance of the two parallel sides of a polygon and add the actual distance between the polygons for the horizontal part. The thickness of a honeycomb cell wall is 0.1 mm, but with the bonding interaction length reduced to a minimum of 0.05 mm. Each the hexagonal cell has the same side lengths with 8 mm. The largest diagonal of the cell cross section is used to define the size of a honeycomb cell and the result is 13.86 mm.



Figure 3.5 Honeycomb cell geometry

Before continue on modelling, the cell dimensions need to be confirmed. In order not to facing any issues in long-run, make sure to fully defined the polygon. After that, apply a linear sketch pattern both vertically and horizontally out of the two polygons indirectly draw

a rectangular as illustrated in Figure 3.6. The value for y-axis is 24.09 mm + 0.09 mm meanwhile, for x-axis is 13.91 mm + 0.05 mm.



After that, the sketch has been be proceed with extrude function for the thickness of the honeycomb. By choosing the extrude, clicking on the distances between of the polygons to develop 3D hexagonal honeycomb as shown in Figure 3.7. Mid plane has been selected for the direction point and the extrude/thickness value is 20 mm.



Figure 3.7 3D Hexagonal honeycomb

Next step is developed 3D of hexagonal honeycomb panel sheets merged by nature fiber composite as illustrated in Figure 3.8. The dimension of the panel sheet is referring with the dimension of hexagonal honeycomb which is 205.53 mm for the width and the length is 104.65 mm. Meanwhile, the value of extrude/thickness for the panel sheet is 5 mm.



Figure 3.8 Sketch and 3D panel sheet 57

Lastly, the 3D part of hexagonal honeycomb and panel sheets be assembled as shown in Figure 3.9 and Figure 3.10 that represented of four view angles of the model. The completed model will be imported to the Ansys software for testing in parameter of thermal analysis.



Figure 3.10 Four view angles of the model

3.5 Simulation Testing

The experiment further focuses on simulation steady-state thermal analysis of 3D honeycomb sandwich reinforced with nature fiber composite model using Ansys software. In general, there are some examples of thermal quantities of interest such as distribution of the temperature, the amount of heat loss or gain, and lastly the gradients and fluxes of the thermal. In Ansys software Mechanical, steady-state thermal as illustrated in Figure 3.11 need to be select for the simulation especially in finding the thermal conductivity for the honeycomb sandwich. To use the steady-state thermal analysis, double click on the icon or drag the icon on the provided box.



Figure 3.11 Steady-State Thermal icon

Next, several steps need to be complete that consists engineering data, geometry, model, setup and lastly solution before obtain the results for the simulation. Engineering data as shown in Figure 3.12, just may simply adjust the material attributes such as aluminium and add varied nature fiber composite with different fiber volume fraction (%) that consists 0 wt.%, 2 wt.%, 4 wt.%, 6 wt.% and 8 wt.% as the new material. In terms of the accuracy of thermal studies, linearity and non-linearity are critical. When the material characteristics change as the temperature rises, nonlinear circumstances are present. Thermal Conductivity is the most significant material parameter to define in Ansys software for steady-state thermal assessments.



Figure 3.12 Engineering data and material selected

Once the materials in engineering data have been selected, import the 3D honeycomb sandwich model to the geometry part as illustrated in Figure 3.13. For the Ansys software solver, the initial temperature must be specified. The initial temperature and final temperature of the model has been obtained during the lab experiments as shown in Table 3.2. So, the simulation results will be compared with the lab experiment results. If the material characteristics are affected by temperature changes, this information is necessary.

•	A	_			
1	🚺 Steady-State Thermal			2	
2	🥏 Engineering Data	× .		1	
3	🞯 Geometry	× ,			
4	Model	2			
5	🍓 Setup	?			
6	Solution	?			
7	🮯 Results	?			
	Honeycomb Sandw	vich	0.00	100.00	200.00 (mm)

Figure 3.13 Imported 3D model to Ansys Workbench

Table 3.2	Initial	temperature a	and final	temperature of honeycomb sandwich during
			🔄 lab e	xperiments

Fiber	Coconut		Sugarcar		Palm Oil		
Fraction (%)	Initial Temp. (°C)	Final Temp. (°C)	Initial Temp. (°C)	Final Temp. (°C)	Initial Temp. (°C)	Final Temp. (°C)	
0 wt.%	42.0 RSIT	32.4 KNIKAI	40.0	28.8 SIA ME	45.3	32.4	
2 wt.%	65 .7	29.7	60.4	26.5	50.8	30. 1	
4 wt.%	72.3	28.3	69.2	24.9	57.5	26.4	
6 wt.%	83.4	25.9	78.0	23.5	63.6	23.6	
8 wt.%	97.8	24.2	88.5	22.8	71.5	21.2	

After the imported model in geometry section be defined by Ansys, proceed with the model section that included assign the materials to each part of the model and setup the important information as illustrated in Figure 3.14. Before continue with the simulation testing, the model needs to be meshed that increases the efficiency to determine the distribution of stress at each and every region. However, some errors happen during the mesh process because the face of honeycomb too much due to the dimension of the model too big and it is also needing too much time to be meshing. To overcome these errors, the model be adjusted by cutting ³/₄ section of the previous model and the new surface area body of the latest model is 16.796 mm² indirectly the extrude/thickness value has been changed to 23 mm as shown in Figure 3.15.



Figure 3.14 Some of the setup in model section



Figure 3.15 New dimension of 3D model honeycomb sandwich

Last but not least, the meshed model as illustrated in Figure 3.16 already in good state and can be proceed with simulation testing. In this case, mesh structure optimization is necessary. Lastly, the solution of the simulation testing can be obtained by choosing the thermal parameter namely temperature and heat flux indirectly using the formula as shown in Figure 3.17, the value of thermal conductivity can be obtained. The value of thermal conductivity honeycomb sandwich reinforced varied nature fiber composite has been recorded on chapter 4, results and discussions.



Figure 3.16 Honeycomb sandwich model that has been meshed



Figure 3.17 Thermal parameter solution and heat flux formula



CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter provides a concise summary of the results and simulation analysis using steady-state thermal Ansys Workbench on the development of 3D hexagonal honeycomb sandwich reinforced varied nature fiber composite in effective thermal conductivity. Simulation analysis be regained by multiple times for different fiber volume fraction at 0 wt.%, 2 wt.%, 4 wt.%, 6 wt.% and 8 wt.% of the model respectively. Comparison of the most effective thermal conductivity between honeycomb sandwich that reinforced with three different nature fibers that consists coconut, sugarcane and palm oil have been recorded in this chapter. The effectiveness of thermal conductivity is proven by simulations carried out and the results are shown in tables and graphs.

4.2 Displayed of Simulation Testing in Thermal Parameter of Temperature and Heat Flux

There is a several results are available for postprocessing of the thermal analysis as illustrated in Figure 4.1. But for our case, the temperature and heat flux will be the objective in finding thermal conductivity using the formula that has been mentioned in previous chapter. Since the temperature is a single scalar number, it has no direction. Therefore, the boundary conditions dictate that the steady-state temperature is zero at the endpoints. Before continue with simulation display results, here is some important tip regarding to the steadystate heat flux. A heat transfer is said to be steady-state if it exhibits a consistent, predetermined rate of heat transfer. Radiation, convection, or conduction are all possible methods of steady-state heat transfer. Simulation testing display for the temperature profile and heat flux of fiber volume fraction at 0 wt.%, 2 wt.%, 4 wt.%, 6 wt.%, and 8 wt.% have been recorded as illustated in Figure 4.2, 4.3, 4.4, 4.5, 4.6 and 4.7 respectively. From the simulation, the most of all the temperature results can be determined in constant steady-state. However, the total heat flux simulation displayed with differents value everytime the testing carried out. It is means the relationship between thermal conductivity of nature fiber composite and the dimension of the model have relatively large influence on determining the value of k that will be obtained is the success in thermal conductivity more efficiently or not.



Figure 4.1 Thermal distribution of the model during simulation temperature parameter





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Figure 4.2 Temperature profile of honeycomb sandwich reinforced coconut fiber composite with fiber volume fraction of (a) 0 wt.% (b) 2 wt.% (c) 4 wt.% (d) 6 wt.% (e) 8 wt.%





Figure 4.3 Total heat flux of honeycomb sandwich reinforced coconut fiber composite with fiber volume fraction of (a) 0 wt.% (b) 2 wt.% (c) 4 wt.% (d) 6 wt.% (e) 8 wt.%





Figure 4.4 Temperature profile of honeycomb sandwich reinforced sugarcane fiber composite with fiber volume fraction of (a) 0 wt.% (b) 2 wt.% (c) 4 wt.% (d) 6 wt.% (e) 8 wt.%





Figure 4.5 Total heat flux of honeycomb sandwich reinforced sugarcane fiber composite with fiber volume fraction of (a) 0 wt.% (b) 2 wt.% (c) 4 wt.% (d) 6 wt.% (e) 8 wt.%





Figure 4.6 Temperature profile of honeycomb sandwich reinforced palm oil fiber composite with fiber volume fraction of (a) 0 wt.% (b) 2 wt.% (c) 4 wt.% (d) 6 wt.% (e) 8 wt.%





Figure 4.7 Total heat flux of honeycomb sandwich reinforced coconut fiber composite with fiber volume fraction of (a) 0 wt.% (b) 2 wt.% (c) 4 wt.% (d) 6 wt.% (e) 8 wt.%

4.3 Thermal Conductivity analysis

Thermal conductivity, or the case with which thermal energy moves from the hot end to the cold end of a substance, characterises the rate of heat flow across a temperature gradient within a material. Watts per metre Kelvin is the thermal conductivity unit in the SI system. A substance with a high thermal conductivity may convey massive amounts of heat fast across a big distance, whereas a material with a poor thermal conductivity can function as an insulating barrier to heat transmission. Thermal interface materials must be able to facilitate heat transmission between two surfaces, which makes thermal conductivity essential. Thermal interface materials are used to 'fill in the gaps' and offer a channel for heat transfer since it may be extremely challenging to get two surfaces to have perfect contact with each other (and hence difficult to achieve ideal heat transfer efficiency). This process also be on of the important things in simulation testing because it can provide more efficient results in finding the thermal conductivity result.

Further the results for the thermal conductivity of the honeycomb sandwich reinforced coconut fiber composite has been recorded as shown in Table 4.4. From the table, a graph has been plotted which is thermal conductivity againts fiber volume fraction as illustrated in Figure 4.8. Clearly we can see that thermal conductivity drop until 6 wt.% of fiber volume and start to rise when reach at point 8 wt.% of fiber volume. It is can justified that the coconnut fiber composite can be effective in thermal conductivity but it is just function at the certain point for example, the thermal conductivity become not effective when the fiber volume too much just like at 8 wt.% and above. Just to mention, the lower the thermal conductivity of a material, the better the thermal performance.

Fiber Volume Fraction (%)	Q (W/mm^2)	Thickness (mm)	L (mm)	W (mm)	Ti (°C)	Tf (°C)	K (W.mm/°C)
0 wt.%	2.98E-19	23	221	76	100	28	5.67E-24
2 wt.%	1.92E-19	23	221	76	100	28	3.64E-24
4 wt.%	1.22E-19	23	221	76	100	28	2.32E-24
6 wt.%	3.89E-20	23	221	76	100	28	7.40E-25
8 wt.%	4.92E-20	23	221	76	100	28	9.35E-25

 Table 4.1 Thermal conductivity of honeycomb sandwich reinforced coconut fiber composite with difference fiber volume fraction



Figure 4.8 The effective thermal conductivity of honeycomb sandwich reinforced coconut fiber composite as a function of fiber volume fraction

Next, the graph as shown in Figure 4.9 that has been plotted in determine the effective thermal conductivity of honeycomb sandwich reinforced sugarcane fiber composite using the collected data as illustrated in Table 4.5. From the graph, we can determine that some errors just happen during the simulation. This is because the thermal conductivity is not

stable and just happen drop and rise at some point. The errors that have been mentioned is thermal conductivity value for sugarcane fiber only not to precise with the dimension and parameter during the setup for simulation testing. Just for sure, the best sugarcane fiber composite volume for the thermal conductivity is 4 wt.% which is 1.60E-24 W.mm/°C. So, for now, honeycomb sandwich reinforced coconut composite is the more effective in thermal conductivity compare to the honeycomb sandwich reinforced sugarcane composite.

 Table 4.2 Thermal conductivity of honeycomb sandwich reinforced sugarcane

 fiber composite with difference fiber volume fraction

Fiber Volume Fraction (%)	Q (W/mm^2)	Thickness (mm)	L (mm)	W (mm)	Ti (°C)	Tf (°C)	K (W.mm/°C)
0 wt.%	2.98E-19	。 23	221	76	100	28	5.67E-24
2 wt.%	3.17E-19	23	221	76	100	28	6.03E-24
4 wt.%	8.40E-20	23	221	76	100	28	1.60E-24
6 wt.% 🗧	1.27E-19	23	221	76	100	28	2.42E-24
8 wt.%	1/2,01E-19	23	221	76	100	28	3.83E-24





The last material that has been used in finding the most effective thermal conductivity is honeycomb sandwich reinforced palm oil fiber composite. The data and result during simulation session has been recorded as shown in Table 4.6. Using the data in the table, a graph has been plotted as illustrated in Figure 4.10. This graph is more stable compare to the honeycomb sandwich reinforced sugarcane composite but the value of thermal conductivity is still high which is 2.68E-24 W.mm/°C.

 Table 4.3 Thermal conductivity of honeycomb sandwich reinforced palm oil fiber composite with difference fiber volume fraction

Fiber Volume Fraction (%)	Q (W/mm^2)	Thickness (mm)	L (mm)	W (mm)	Ti °C	Tf °C	K (W.mm/°C)
0 wt.%	2.98E-19	23	221	76	100	28	5.67E-24
2 wt.%	2.17E-19	les 23	221	76	100	28	4.14E-24
4 wt.% 🥈	2.01E-19	23	221	76	100	28	3.82E-24
6 wt.% 🗒	1.41E-19	23	221	76	100	28	2.68E-24
8 wt.% 🖏	1.73E-19	23	221	76	100	28	3.28E-24





The last graph as shown in Figure 4.11 determines which is the most honeycomb sandwich reinforced varied nature fiber composites in effective thermal conductivity. According to the graph, the most qualified and efficient in thermal conductivity is honeycomb sandwich reinforced coconut fiber composite which is 7.40E-25 W.mm/°C at 6 wt.% of fiber volume. The second is honeycomb sandwich reinforced sugarcane fiber composite with 1.60E-24 W.mm/°C thermal conductivity at 4 wt.% of fiber volume for the material composition. The last one that not too good on effective thermal conductivity is honeycomb sandwich reinforced palm oil fiber composites. The value of thermal conductivity that it has is 2.68E-24 W.mm/°C at 6 wt.% of fiber volume.



Figure 4.11 Comparison in effective thermal conductivity among the honeycomb sandwich reinforced varied nature fiber composites

4.4 Summary

This chapter can conclude on presentation of the data and results are enhanced by the simulation testing and so on. It is also described on the effective thermal conductivity for a material by making comparison the three-honeycomb sandwich reinforced nature fiber composite. The graph and explanation have been attached. Besides, the simulation testing must find temperature and total heat flux in order to calculate thermal conductivity, k using the formula that has been mentioned on previous section. Lastly, it is also displaying the temperature profile and heat flux of 3D Honeycomb sandwich reinforced nature fiber using Ansys.



CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In practice, there are many methods that can be applied in finding thermal conductivity of material doesn't matter in terms of lab experiments or through simulation experiments. For this research, it is focusing on simulation expriments that using Solidworks software on develop the 3D model hexagonal honeycomb sandwich reinforced varied nature fiber composite and Ansys software for the simulation in finding thermal conductivity effectiveness.

The first objective of this research is to develop 3D sandwich model of thin-walled honeycomb with nature fiber composite panel using fiber random distribution method. In order to accomplian this objective, the model need to be aketch roughly before continue with modelling using the software. Dimension of the model need to be reconfirmed exactly with the parameter that will be used. Using the function in Solidworks software, the modelling can be developed by linear sketch pattern and extrude function for the thickness. The unit for the dimension must be clearly justified through the modelling in order to avoid any error happens. Once the part of hexagonal honeycomb modelling be done, continue with the modelling with the both parts, assemble them to the specific point (reference line) on each surface selected before become 3D hexagonal honeycomb sandwich with the plate that reinforced as the nature fiber composite during simulation session. In this research, the second objective was to investigate thermal conductivity performance by varied nature fiber component content. Investigation on thermal conductivity performance be carried out by using Ansys software. The completed 3D model design needs to be import to the Ansys Workbench for the simulation experiments and the file should in IGES type. The parameter for the research is related to the thermal so, steadystate thermal analysis be selected. Firstly, engineering data need to be setup by choosing the material that is going to use. It is can be done by add the material in the library data but, the new material need to be put the thermal conductivity value. Here the crucial part because it will determine the material valid or not for the simulation. Proceed with the model or setup by assign the material to the each part of the model, determine thermal load for the simulation for example temperature surface, heat flow and so on. Before continue with solution simulation, the model needs to be meshed in order getting the most accurate results.

Lastly, the results from the simulation can be used especially total heat flux (q) in order to calculate thermal conductivity using the selected formula. Thermal conductivity (k) of honeycomb sandwich reinforced varied nature fiber composite at 0 wt.%, 2 wt.%, 4 wt.%, 6 wt.% and 8 wt.% can be determined and honeycomb sandwich reinforced coconut fiber composite has the most effective thermal conductivity compare to the others. It is also be proven by the lab experiments that's also honeycomb sandwich reinforced coconut fiber composite has the lowest value of k. Overall, the lower the thermal conductivity of a material, the slower the rate at which temperature differences transmit through it.

5.2 Recommendations

This research could benefit from a few recommendation for further improvement. The following are the suggestion:

- The dimension of model sample should be exactly same with the lab experiment and simulation experiment which is different dimension will causing the value of k not same.
- Thermal conductivity (k) of nature fiber composite should be tests during the lab experiment regarding to the our model sample. It is important because the simulation experiment need to key-in the value of k as the new material.
- iii) 3D model need to be modelling properly before continue with the simulation because mesh process cannot be run if the 3D model have errors. Besides, the more complicated the design, the more time taken for meshing process. So, make sure the design do not have any issues.

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iv) Apply validation method by make sure the thermal conductivity of honeycomb sandwich reinforced nature fiber is same with simulation testing and lab experiment.

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