MESO-SCALE MODELLING OF PULTRUDED HYBRID COMPOSITE UNDER IMPACT LOADING

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LIST OF SYMBOLS

E	Young's modulus
υ	Poisson ratio
ε	strain
έ	strain rate
σ	stress
π	pie
V	volume
h	height
ρ	density
U	displacement
UR	rotational displacement

LIST OF ABBREVIATIONS

SHPB	Split Hopkinson Pressure Bar
BC	Boundary condition
CFRP	Carbon fiber reinforced plastic
NFRP	Natural fiber reinforced polymer
PMC	Polymer matrix composites
PVB	Polyvinyl butyral
SFRPC	Synthetic Fiber Reinforced Plastic Composite
SEM	Scanning electron microscope
FEA	Finite element analysis
UTM	Universal tensile machine
GFPP	Glass Fiber reinforced Polypropylene

ABSTRAK

Komposit adalah satu bahan dimana sepanjang tempoh penggunannya, ia telah terdedah dengan pelbagai tahap tegangan mekanikal yang berbeza serta terkena pelbagai keadaan cuaca yang melampau. Secara amnya, terdapat tiga jenis komposit yang digunakan dalam industry seperti, composite semula jadi, komposit buatan dan komposit campuran. Komposit campuran kenaf/kaca adalah bahan yang akan digunakan dalam kajian untuk projek tahun akhir ini.

Kedua-dua komposit semulajadi dan komposit buatan mempunyai kebaikan dan keburukan masing. Oleh itu, bagi menambahbaik sifat bahan tersebut, komposit diperkenalkan dan digunakan dalam industry. Walaubagaimanapun, kajian yang dijalankan mengenai cara komposit campuran bertindak apabila dikenakan impak muatan masih terhad. Kajian ini dijalankan dengan menggunakan perisian Abaqus untuk meniru sistem pemeriksaan yang kebanyakkan digunakan dalam industry iaitu sistem pemeriksaan SHPB. Bagi memastikan simulasi ini dapat dijalankan, beberapa jurnal telah digunakan sebaga sumber rujukan untuk mencari data mengenai parameter yang digunakan. Perisian Solidwork 2019 juga digunakan untuk membuat rekaan spesimen sebelum dimasukkan di dalam Abaqus.

Berdasarkan hasil dapatan daripada simulasi yang dijalankan, pergerakan tegangan, pengagihan tegangan dan mod kegagalan dikenalpasti. Serta kaca adalah bahan yang akan banyak menampung tegangan yang dikenakan semasa impak berlaku. Perubahan bentuk juga dapat dilihat pada sisi matrik komposit itu.

ABSTRACT

Composite is one of the substances that, during the course of their life cycle, have been put through a range of mechanical stresses and been subjected to harsh climatic conditions. Genarally, there are three type composite in the industries which is natural composite, synthetic composite and hybrid composite. Kenaf/glass hybrid composite is the type of material which will be futher study in this project.

Both naturally occurring fibres and manufactured fibres may be used to strengthen composite materials, each of which comes with their own set of benefits and drawbacks. In order to enhance the qualities of the composite material, the hybrid composite was developed and implemented. However, there has only been a very limited amount of research done on how hybrid natural composites behave when subjected to impact loading. The study about the composite was done by using Abaqus 2021 software which used to imitate the testing system that is widely used in the industries which is SHPB test. Several journal has been study to find out suitable parameter and setting to be used along the simulation process. before proceeding with simulation, the model of specimen was created by using Solidwoks 2019.

Based on the finding from the simulation, stress propagation, stress distribution and failure mode occur in the simulation can be observed. Glass fiber is the component wear its bear most of the load which is come from the impact of the striker bar. The deformation of the fiber also can be seen at the edge of the matrix.

CHAPTER 1

INTRODUCTION

1.1 RESEARCH BACKGROUND

Composite is one of the materials that have been subjected to a variety of mechanical loads and exposed to extreme environmental conditions over their life cycle.(*Natural lightweight hybrid composites for aircraft structural applications _ Elsevier Enhanced Reader.pdf*, n.d.) Natural fiber-reinforced composites have the potential to be used as a material for strong components such as construction materials, automobile parts, and other similar applications like shipping, automobile, and other industries. Because natural fiber-reinforced composites are relatively strong, lightweight, and contain no health hazards, they have the potential to be used as a material for strong components. [2] To reduce the weight of the vehicle, car manufacturers started to substitute steel with composites. It has been claimed that a 25 percent reduction in the weight of automobiles may save as much as 250 million barrels of crude oil.[1] Fiber-reinforced polymer composites have a variety of physical and chemical properties to offer when viewed at the micro and macroscopic sizes. Because of this, several engineering and structural sectors have expressed an interest in the issue. It's also a good approach to increasing the weight-to-strength ratio of your vehicle. The use of fiber-reinforced composites, which are widely employed in the military, as well as the marine, aerospace, and civil engineering industries, has brought about several positive changes in the present industrial world. When subjected to impact damage, composites, on the other hand, are both expensive and difficult to repair. [3] Natural fibers and synthetic fibers are the two types of fibers available fiber manufacturing industry. Chemically synthesized fibers are widely employed in the composites and associated engineering sectors, and they are significantly more costly than natural fibers. Natural fibers that are often found in nature are not the first option for composite reinforcement in structural applications. Natural fibers come from animals or plants and are called "natural fibers." Bamboo, hemp, sisal, kenaf, and flax are among the plant-based fibers that researchers are studying in the automobile business. These fibers are beginning to get attention as alternative automotive component materials in the industry. [3]

The term "hybrid composite" refers to materials that have been manufactured by merging two or more distinct types of fibres within a single matrix to produce a composite material with enhanced performance. Different researchers have come up with a variety of distinct definitions of hybrid composites. These definitions can be found such as, hybrid composites are made up of reinforcing materials that have also been mixed with a variety of different matrixes. Composites, on the other hand, are made up of a reinforcing material that is included into two or more reinforcing and filling materials that are all included within a single matrix of materials. This matrix of materials is known as the matrix of the composite. The standard fiber-supported composites are more simplistic in comparison to hybrid composites, which are more complex and have a greater variety of applications. [1]

Experiments and numerical simulations have both been utilised in the various research efforts that have been conducted on the topic of the mechanical behaviour of composite materials. The difficulty of carrying out tests with specific configurations or monitoring the emergence of internal damages at varying loading levels is one of the reasons why numerical simulation is so important in this case. This simulation is typically carried out by employing a technique known as the finite element approach.[4] Mechanical characteristics, crack initiation and propagation, reinforcement matrix interfacial behaviour, viscoelastic and plastic behaviour, and energy absorption capacities are just a few of the phenomena that FEA can simulate and predict.[5]

In this study, the simulation will be focused on pultruded hybrid composite which is the combination of kenaf fiber and glass fiber. In the industry, pultrusion is a continuous fiber laminating method that is highly automated and produces high-volume fiber profiles with a constant cross-section. It is drawn into the heated pultrusion die from the impregnated reinforcement region in the infeed area. The kenaf plant is the source of the natural fibre that was utilised in the construction of this composite for the purposes of this study as shown in the Figure 1.1. In Polymer Matrix Composites (PMCs), one of the natural (plant) fibers utilized as reinforcement is kenaf, which is a type of natural fiber. Its scientific name which is Hibiscus cannabinus (L. family Malvacea) has been discovered to be a valuable source of fiber for composites and other industrial purposes. [6]

Figure 1.1: Kenaf plant

As mentioned earlier in this proposal, we also use synthetic fiber in this hybrid composite which is glass fiber. Glass fiber was selected as the material for this investigation because it is a versatile material that can be used in both industrial and domestic applications. [7] As shown in figure 1.2 the percentage of the usage of glass fiber in various applications.

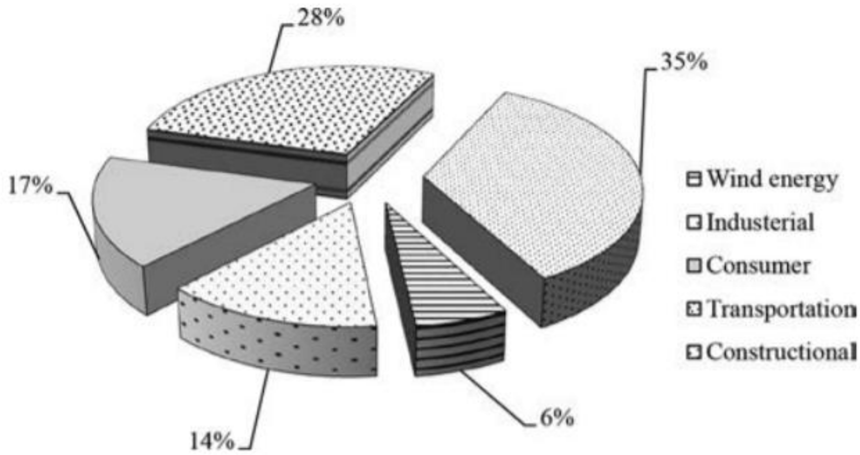

Figure 1.2: The percentage of various types of fibre in each application

1.2 OBJECTIVE

1. To develop a meso-scale model of kenaf/glass hybrid composite.
2. To identify the stress distribution and concentration in kenaf/glass hybrid composites under impact loading.

1.3 PROBLEM STATEMENT

In the past ten years, the usage of composite in various types of industries get high demand due to its greater strength compared to other conventional metal structures. In the context of natural composite material their advantages include having low density and cost, high specific strength, and being sustainable and environmentally friendly, while in synthetic composite materials are stronger and longer-lasting than their all-natural counterparts because they're specifically engineered fro cpecific purpose . Therefore, the hybrid composite was introduced to improve the properties of the composite. There is a very limited review on the behavior of the hybrid natural composite under impact loading. The objective of this study is to carry out mesoscale modeling of the pultruded hybrid composite under impact loading. Hence, stress distribution, stress propagation, and its failure effect will be observed throughout the simulation. By including FEA in any product development process, the effects that real world extremes will have on the design can be simulated before physical prototype be created. This virtual prototyping saves substantial time and cost by minimising the number of physical prototypes required. [8]

1.4 PROJECT SCOPE

In the context of this study, it is necessary to carry out finite element analysis in order to investigate the behaviour of the hybrid composite. The simulation was carried out with the aid of two distinct pieces of software, namely solidwork 2019 and Abaqus 2020. The model of kenaf/glass hybrid composite is modeled in Solidworks according to the dimension got from the literature review. Then the model needs to be assembled in the SHPB model which was set up in the Abaqus software. While build up the setup of the model in the Abaqus, several facto need to be consider such as, velocity impact, boundary condition, material orientation, surface contact and meshing. Then, the outcome of the analysis has been verified and supported by the experimental study to ensure the result is reliable.

CHAPTER 2 LITERATURE REVIEW

2.1 NATURAL COMPOSITE

Our knowledge of the dynamic mechanical characteristics of natural fibre reinforced composites is extremely restricted at the moment. Most of the data is quasi-statically collected using Universal Tensile Machine with a limitation of strain rate $0.1s^{-1}$. Because there is a poor understanding of the material's strength when it is subjected to impact loading, the material will be applied in the design in a manner that is wasteful and ineffective. This is because there is no way to determine the strength of the material in advance. This is because there is no way to determine the strength of the material in advance. Therefore, there is a need to document the behaviour patterns of kenaf-glass hybrid composites while they are subjected to a high strain rate in order to make it possible for these composites to be utilised successfully in a number of applications that require high performances. Investigation on the behaviour of the material when subjected to high strain rates has made use of a number of different dynamic devices, such as the Split-Hopkinson pressure bar, the Kolsky bar, the flying wedge, and the air gun system. However, SHPB is the most suitable device to be used because of its simplicity of setup and operation compared to other methods.

The natural fiber is classified according to whether it comes from plants, animals, or minerals. Cellulose is the primary component of plant fibres, while proteins make up the bulk of animal fibres. There is a wide variety of plant fibres available, some of the most common of which include bast, leaf or hard fibre, seed, fruit, wood, cereal straw, and grass fibre. There are several types of natural fiber available as shown in figure 2.2. Natural fibers are less expensive than synthetic fibers since they are plentiful and made from renewable resources. As a result, the commercial and research potentials of Natural Fiber Reinforced Polymer (NFRP) composites are greatly enhanced. [9] As a consequence of this, natural fibres and biodegradable polymers have arisen as viable options for use in the composites industry. Many research organizations across the world have created promising materials consisting of biodegradable fibers and polymers to form new types of biocomposites to replace conventional materials in the last year. Due to their numerous benefits, including their biocompatibility, recyclability, renewability, availability, penetrability, damage tolerance, high level of flexibility, hygroscopicity, non-toxicity, ability to release harmful substances, non-irritation to the skin, lack of allergic reaction, competitive mechanical properties, and decreased energy consumption, natural fibre composites are suggested to replace synthetic fibre composites.[9] One of the application of the NFRP is new bone fixator by using cocoon silk as treatment for bone fracture. In the conventional method, two different surgeries need to be performed which is during the installation of the metal bar on the bone and another one is the removing process of the metal bar after the bone fully recoverIn addition, the natural fibre has features that enables it to be bio-resorbable or bio-degradable, which means that it has the ability to break down and be absorbed by the human.[10]

Natural fiber consists of many different structures at microscopic view. The core the of microfibril which also known as lumen are covered with different layer of wall. Each one of the walls are built up with microfibril with different orientation. The microfibrillar angle is the primary factor that determines the tensile strength of natural fibres. Based on the figure 2.1, When all of the microfibrils in an NFRP composite are aligned along the direction of the fiber that is along the direction in which tensile loading is applied there is, a significant increase in the tensile modulus of the composite.[10]

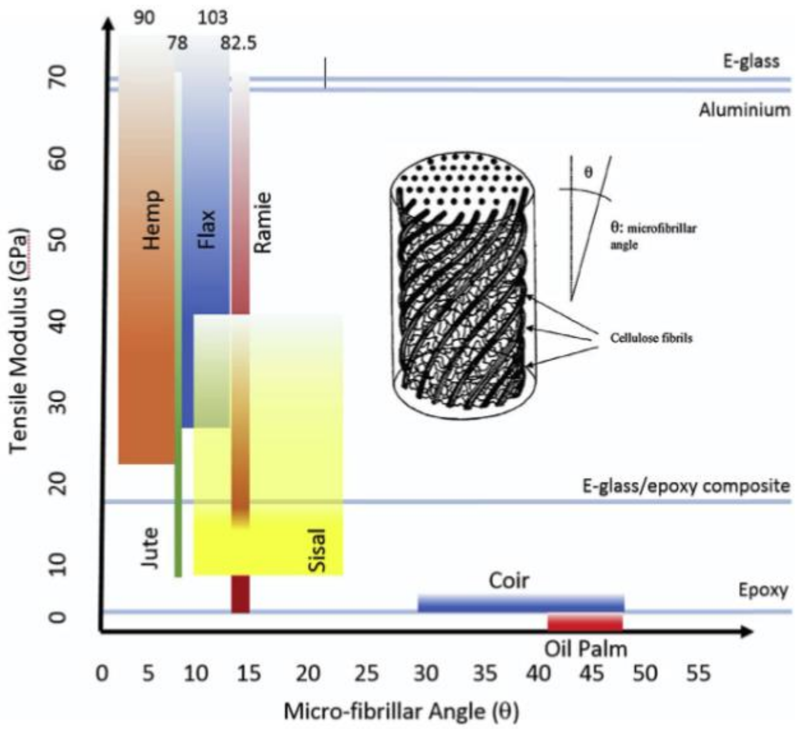

Figure 2.1: Relationship between micro-fibrillar angle and tensile modulus

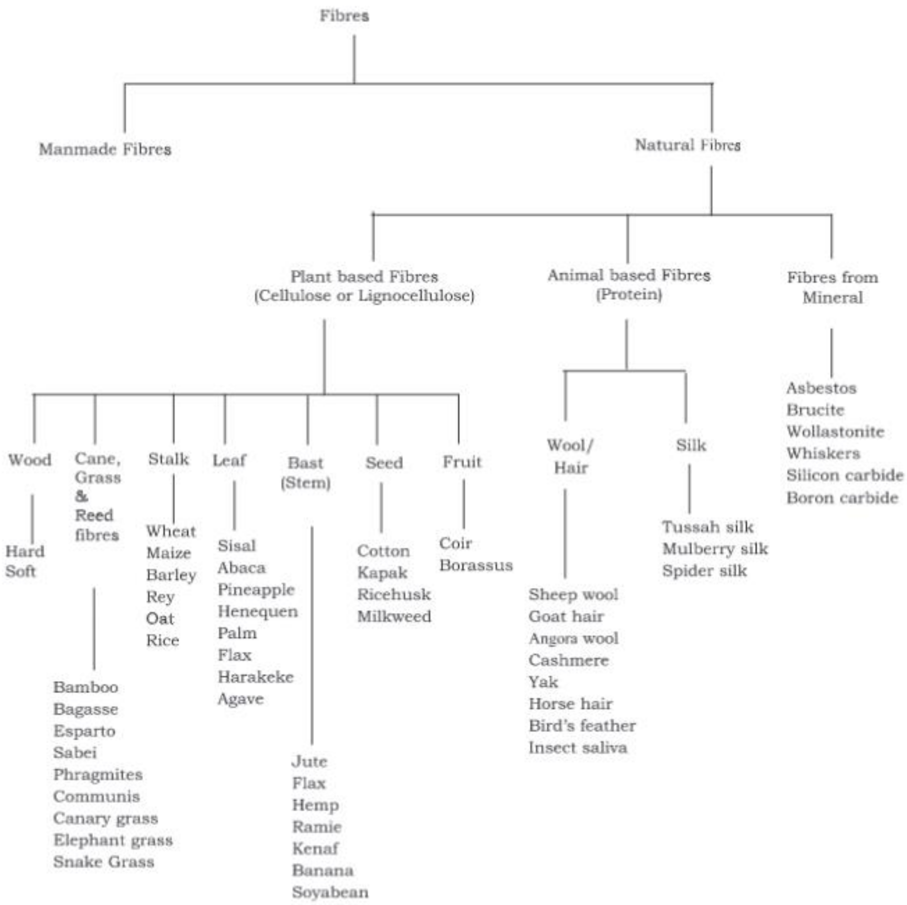

Figure 2.2: Classification of natural fiber

Even though they have the advantages described above, there are certain disadvantages, such as poor moisture resistance, particularly absorption, and low strength when compared to synthetic fibres such as glass and polyester. When placed in an environment with a high relative humidity, or even just submerged in water, all of the several types of polymer composites that were evaluated showed signs of moisture absorption. The ability of natural fibre composites to absorb moisture is an additional advantage that they offer. So because fibre has a hydrophilic character, it is especially prone to the absorption of water, which causes the fiber's physical qualities to be unstable. This is the direct outcome of the hydrophilic nature of the fibre. When composite materials are exposed to moisture, the micro gaps that exist between the polymer chains get compromised, which leads to the material's degradation. When placed in a setting with a high relative humidity, all types of polymer composites that were examined absorbed moisture, regardless of whether they were immersed in water or not. Two of the more common mechanisms of water absorption are capillary transport into gaps and faults at the interfaces between fibres and polymer, caused by incomplete wettability and impregnation, and transport through microcracks (produced during the process of compounding) in the matrix. Capillary transport into gaps and faults at the interfaces between fibres and polymer is caused by incomplete wettability and impregnation.[2] Microcracks allow moisture to seep through them. The hypothesis was tested by [11] conducting an experiment in which a comparison of the composite's mechanical properties was made after being exposed to a variety of different environments as shown in the Table 2.1.

Table 2.1: Tensile strength of hybrid composite in varying conditions of the environment

	Tensile Modulus (GPa)				
	1st day	1st week	2nd week	3rd week	4th week
Standard	8.36	8.36	8.36	8.36	8.36
Distilled water	6.53	6.66	6.46	6.83	5.64
Rain water	8.27	6.65	6.92	6.74	6.06
Sea water	7.19	7.15	6.37	6.64	5.80

The tensile modulus of immersed kenaf fibre reinforced composites decreased as a result of damage to the matrix, a decline in interfacial adhesion, and a weakening of the bond strength between the matrix and the fibre. When water molecules penetrate a polymer, two processes known as hydrolysis and plasticization of the matrix will take place. Both of these processes will lead to the breakdown of the chemical bonds and combinations that hold the polymer together. As a result of the weakening of the interfacial bonding, there is poor adhesion between the polymer chains, and the tensile modulus of the material is reduced.The moisture content of the matrix and fibres causes the tensile modulus to go down, which is why it is less strong. When there is more moisture in the polyester matrix and the kenaf fibre, which are both hydrophilic and have numerous hydroxyl groups (-OH) in the fibre structure, a lot of hydrogen bonds are produced. This is because both of these components are hydrophilic. In this case, when more time is spent in water, the tensile modulus goes down because of this chemical reaction.[2]

2.2 FAILURE OF NATURAL COMPOSITE

Matrix cracking, delamination, fibre failure, and penetration were among the damages caused by the low-velocity impact event that happened. Matrix cracking is the initial stageof damage due to low velocity impact. When a greater external load is applied, the number of cracks will rise, which will eventually lead to another failure known as delamination. Delamination was found to be induced by matrix cracking when significant transverse shear stresses were present at the nearby affected matrix surface and afterwards developed into a weak interfacial bond, which further developed into fibre fracture and fibre pull out. When the percentage of kenaf fibre in the polyvinyl butyral (PVB) was increased from 10% to 20% and 30%, the material's impact strength showed an upward trend. However, the material's impact strength was at its greatest when it contained 40 percent kenaf fibre. However, the impact energy strength of the composite started decreasing at 50% and 60% fibre content.[6] It is well knowledge that the primary mechanism of compression failure in kenaf composites is fiber-matrix contact bonding, which impedes the ability of the material to perform mechanical function. Principally, the mechanical properties of natural fibre reinforced composites strongly depend on the interface adhesion property between the fibres and the polymer matrix as observed by numerous investigators. [9] Fiber will behave differently when exposed to impact loading between experimental and simulation because of the present of heat during experimental procedure. Figure 2.3 shows a comparison of the stress versus curves generated by the finite element model and those generated experimentally under varying strain rates. One of the reason for variation of the result between simulation ans experimental because the present of the heat in the experimental which will increase the mobility of particle in composite[12].

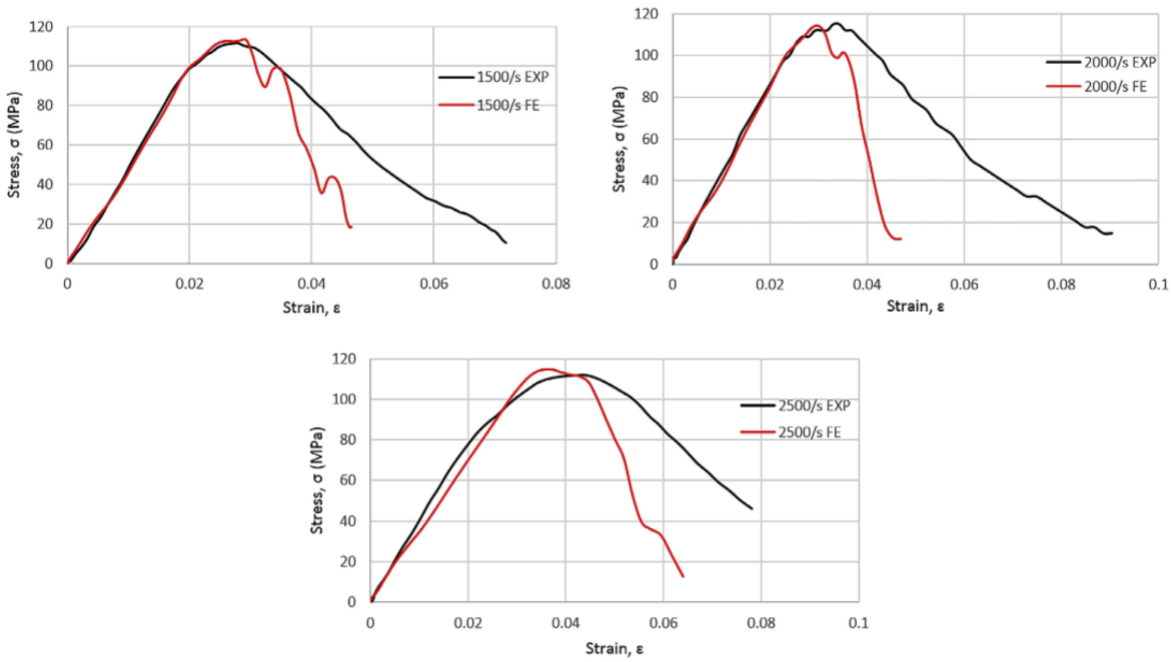

Figure 2.3: A comparison of the stress versus curves generated by the finite element model and those generated experimentally under varying strain rates

2.3 SYNTHETIC FIBRE

Raw materials such as petroleum are used in the production of synthetic fibres, which are then processed using chemical or petrochemical processes. These components are polymerized into long, linear chemical chains with a variety of chemical compounds before being utilised in the production of a wide variety of fabric types. The fabrication of synthetic fibres can be accomplished through a variety of processes, but the met-spinning method is by far the most prevalent. The fibre is heated up until it begins to melt, and then it is extracted from the molten state using tweezers as rapidly as possible. The process entails heating the fibre. The next step would be aligning the molecule in a parallel arrangement. As a result, the fibres are brought closer together, which paves the way for them to crystallise and orient. Synthetic fibres such as glass, carbon, aramid, Kevlar, and others are the primary materials utilised in the production of FRPCs. In comparison to monolithic polymer materials, synthetic FRPCs provide a number of distinct benefits. These composites not only have high strength and high stiffness, but they also have a long fatigue life and the capacity to adapt to the function that is intended for the structure. Further enhancements are also possible in the synthetic FRPCs in terms of their resistance to corrosion and wear, appearance, temperature-dependent behaviour, environmental stability, thermal insulation, and conductivity. Although the Synthetic Fiber Reinforced Plastic Composite (SFRPC) possesses a unique mechanical strength, it does have a number of significant drawbacks, such as a high price, a greater density (when compared to polymers), and poor recycling as well as non-biodegradable properties. Despite these drawbacks, the SFRPC is still widely used because of its exclusive mechanical strength. These drawbacks prevent the material from being used in many applications. Glass fibre is a lightweight material that is incredibly tough and strong despite its low weight. When compared to metals, its bulk strength, stiffness, and weight qualities are likewise in a far more favourable position. In order to create a stronger structure, the matrix of polyester resin was reinforced with E-glass fibres that had a random orientation.[13] Glass fibre was the type of synthetic fibre that was utilised for this research. Glass fibre, in its most fundamental manifestation, is an amorphous (non-crystalline), homogeneous network of silica, oxygen, and other atoms that are dispersed at random throughout the fiber's three-dimensional structure. Glass is made in several ways, which produces fibers with qualitatively distinct qualities depending on the system used to make them as shown in Table 2.2 below. [14] The amount of the fiber also will affect the tensile strength of composite. Table 2.3 shows the the effect of the percentage of glass fibre in manufactured composites on their tensile strength.

Table 2.2: Properties of E glass fiber and unsaturated polyester resin

Property	Tensile strength (MPa)	Compressive strength (MPa)	Elastic modulus (GPa)	Density (g/cm^3)
E-glass	3445	1080	73	2.58
Unsaturated polyester	90	55	3.23	1.35

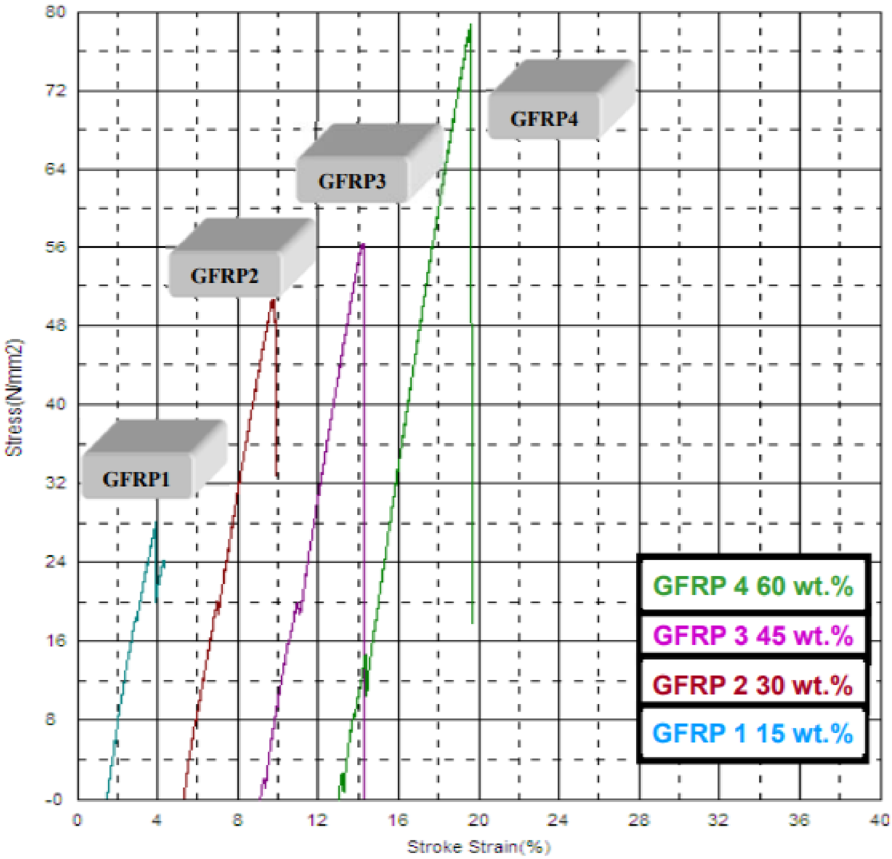

Figure 2.4: The variation in tensile strength with the glass fiber ratio from 15 wt.% to 60 wt.%

Table 2.2: The effect of the percentage of glass fibre in manufactured composites on their tensile strength

No.	Content (%)	Width (mm)	Thickness (mm)	Max. Load (N)	Yield strength (MPa)	Tensile strength (MPa)
Control sample	0 %	19	5	2707.50	10.29	19.76
GFRP 1	15 %	19	5	3504.30	18.63	28.25
GFRP 2	30 %	19	5	4827.90	20.32	50.82
GFRP 3	45 %	19	5	5370.35	21.08	56.53
GFRP 4	60 %	19	5	7488.85	12.54	78.83

2.4 HYBRID COMPOSITE

In the fabrication of hybrid composites, two or more different types of fibers are combined within a common matrix to form a composite material. According to the definitions offered by some academic publications, a hybrid composite consists of a reinforcing element that is integrated into a mixture of various matrixes.[15] The performance of a hybrid composite is an output of the individual fiber, which is responsible for finding the right balance between the material's advantages and disadvantages. In a hybrid composite, the benefits of one type of fibre might be able to improve the quality of other components. For example, kenaf-aramid with Kevlar, woven jute/glass fabric, and sisal fiber-reinforced polyester composite with the addition of carbon are all examples of hybrid composite materials.[16]

A variety of factors, such as the orientation of the fibres, the amount of fibre that is present and its length, the layering pattern of the two fibres, their intermingling capacities, the fiber-matrix interface, and the failure strain of the individual fibres, can all have an effect on the properties of a hybrid composite material. When it comes to the design and production of hybrid composites, the most challenging parts are those that arise during the selection of compatible fibre and the degree to which the fibre possesses a certain degree of its physical attributes.[17] During the process of designing and manufacture the composite, it comes with different arrangement of the fiber in the matrix as shown in the figure 2.5 [18].This study has been focus on the pultruded composite which is also known as unidirectional composite.

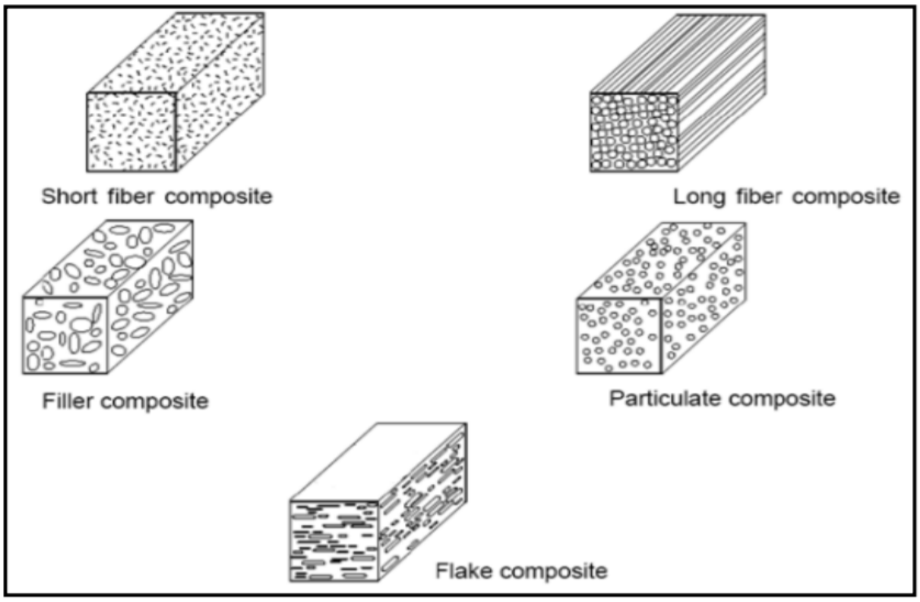

Figure 2.5: Different configuration of the fibre in the composite.

2.5 MECHANICAL PROPERTIES OF KENAF/GLASS FIBER COMPOSITE

In this illustration of figure 2.6, the tensile strength and tensile modulus of the composite laminates are shown. When glass fibre was incorporated into composite laminates, a significant increase in the tensile strength of the composite laminates was achieved. Because of this, glass fibre has a greater capacity for withstanding mechanical stress than kenaf fibre does. The extremely high mechanical strength of glass fibre led to a beneficial hybrid effect, which resulted in an augmentation of the material's tensile capabilities. The tensile characteristics of composite laminates saw an increase in improvement in proportion to the amount of glass fibre layers present in the laminate. Fiber pull out, debonding, and fibre fracture are the three most common types of damage. Fiber pull out is the most common. It was obvious that the composite that had been reinforced with glass fibres had a greater degree of visible fibre pull-out as well as fibre-matrix debonding. [19]

This can be explained because there was insufficient interfacial connection between the matrix and the glass fibre. The surface of the fibres has a significant impact on the interfacial bonding. The interfacial bonding of kenaf fibre is superior to that of glass fibre as a result of the rougher surface of the kenaf fibre when compared to the surface of glass fibre. In light of the findings that fibre breaking, fibre pull-out, and fibre-matrix debonding were observed in the composite laminates, it can be deduced that the fibres and the matrix both perform the function of load carrier. Overall, the damage modes depend on each constituent in the composite materials [2].

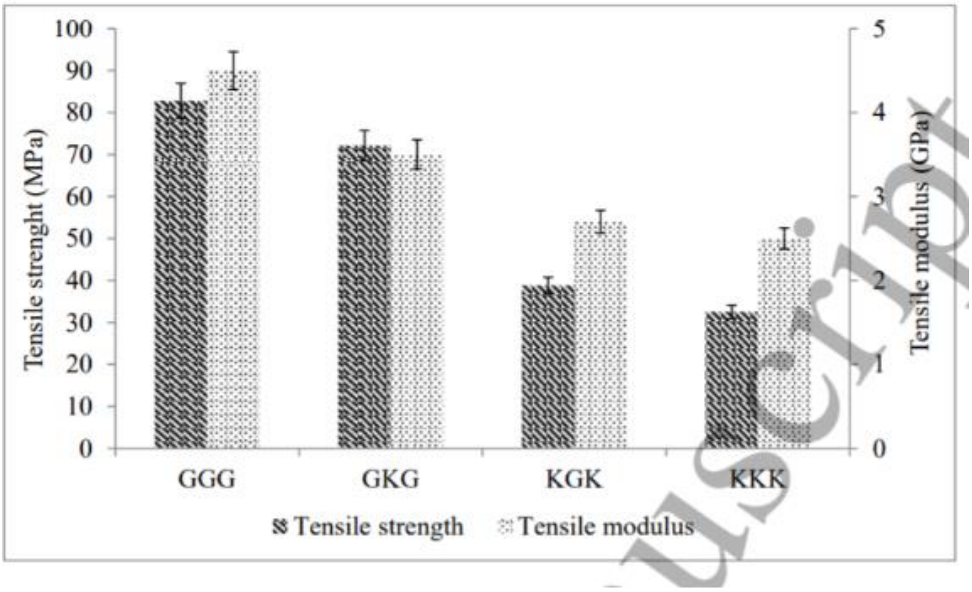

Figure 2.6: Tensile properties of composites laminates

2.6 STATIC AND DYNAMIC LOADING

Static and dynamic loading conditions are both something that can be applied to natural fibre reinforced composites when they are in service. All materials are thought to behave differently under static and dynamic situations. Dynamic mechanical properties of natural fiber reinforced composites at high strain rates, on the other hand, are rarely observed and recorded. Based on this concern, to ensure the safety of natural fiber reinforced composites under high strain rate loading conditions, it is necessary to measure the dynamic mechanical properties of these materials under high strain rate, which is not possible using a standard Universal Testing Machine (UTM).[20]

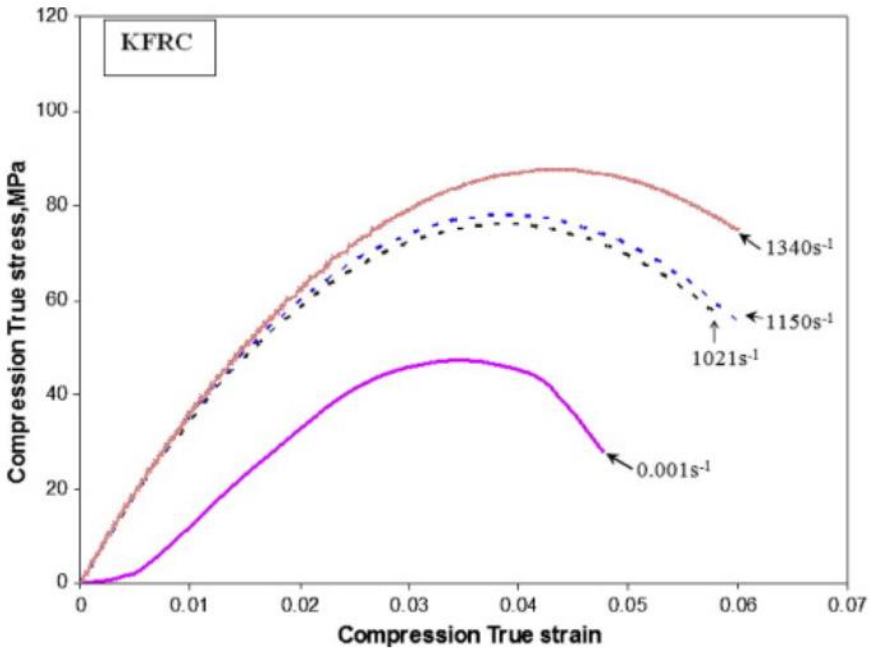

Figure 2.7: compression true stress vs strain

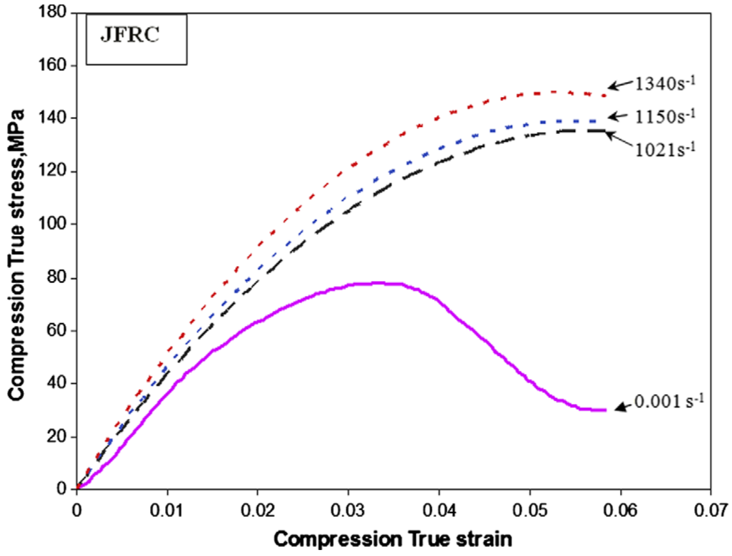

Figure 2.8: The stress–strain curve of jute fibre reinforced composites (JFRC) at various strain rates.

Based on the comparison down by the previous study, different strain rate in test can give different behaviour of the material. As shown in the figure 2.7 and figure 2.8, the levels of strain rate have a significant impact on the behaviours of reinforced composites. Of course, as the strain rate rises, the yield stress and flow stress of the composites also increase significantly. Additionally, as the strain rate rises, the polymer chains' molecular mobility will decrease and the material will stiffen as a result.[20]

CHAPTER 3

METHODOLOGY

3.1 FINITE ELEMENT ANALYSIS

In this project, a standard/explicit model has used. Some basic steps can be followed to perform a standard/explicit model analysis. The steps mostly include model geometry creation and mesh, identification of the contact pairs, designated contact, and contact surface, setting the element key options and real constants, defining the motion of the target surface (only for rigid-to-flexible), applying boundary conditions and load, define solution options and load steps, solve the contact problem, and review the results. Figure 3.1 shows the flow chart of the contact analysis in this project.

There are three types of scale used in modeling the part micro-scale, macro-scale and Mesoscale. A study of the behaviour of composite materials at the microscale, in which interactions from constituent materials are investigated in greater depth, is called a microscale study. Heterogeneous material behaviour is the defining characteristic of composite material behaviour. While macroscale is a study of material behavior which is considered to be homogenous. Effects of all constituent materials are detected only by the material's mean properties. Lastly, mesoscale is the method where the material's heterogeneities are represented explicitly. At the laminar level, the composite is thought of as a single material that is both isotropic and orthotropic in the transverse direction.Based on the type of scale represented above, mesoscale is the most suitable scale to be used in the simulation of the kenaf-glass hybrid composite in Abaqus software. As a result, we are required to provide the material attributes for each of the components, which are kenaf fibre, glass fibre, and unsaturated polyester as the matrix phase respectively.

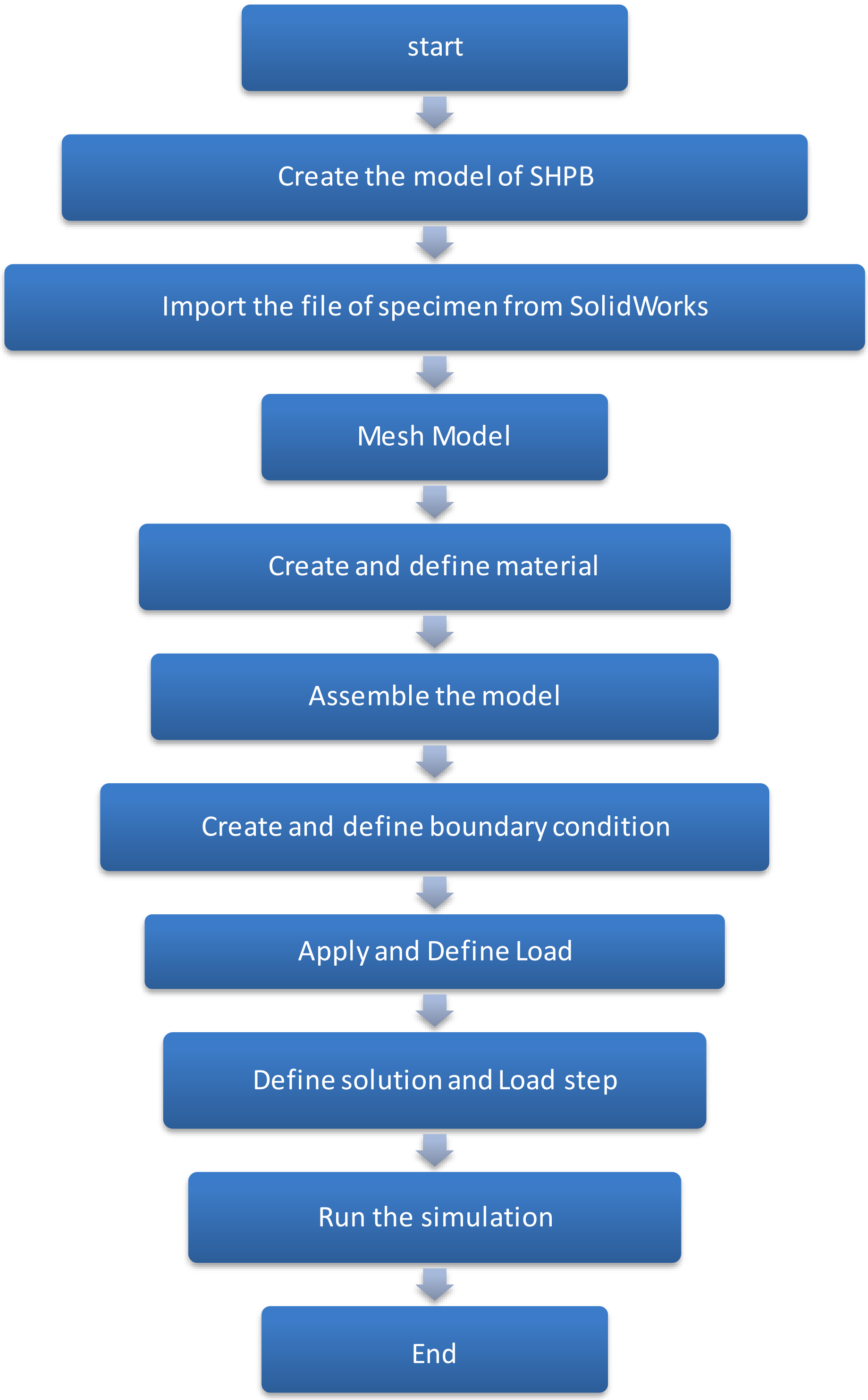

Figure 3.1: Flow chart of the analysis

3.2 CAD DESIGN

The model of the specimen was done by using SolidWork because it is much easier to be created. The specimen consists of several parts which are glass fiber, kenaf fiber, and matrix part as shown in figure 3.2, figure 3.3, and figure 3.4 respectively. The length of the kenaf fiber, glass fiber, and matrix part are 20mm with a diameter of Ø1.27mm, Ø1.27mm, and Ø12.00mm respectively.

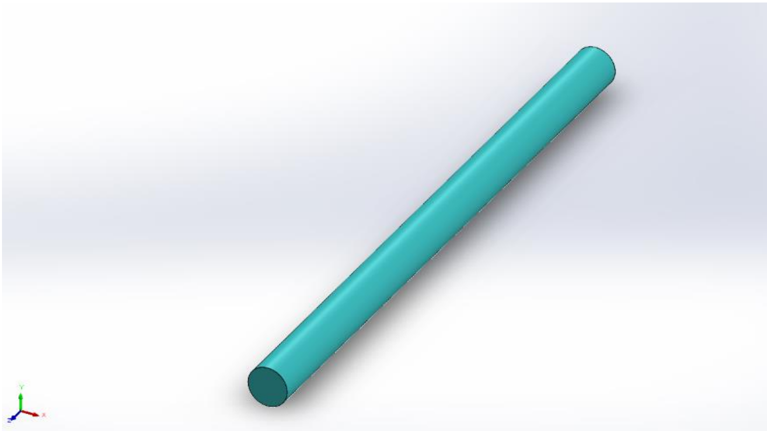

Figure 3.2: CAD model of glass fibre.

Figure 3.3: CAD model of kenaf fiber

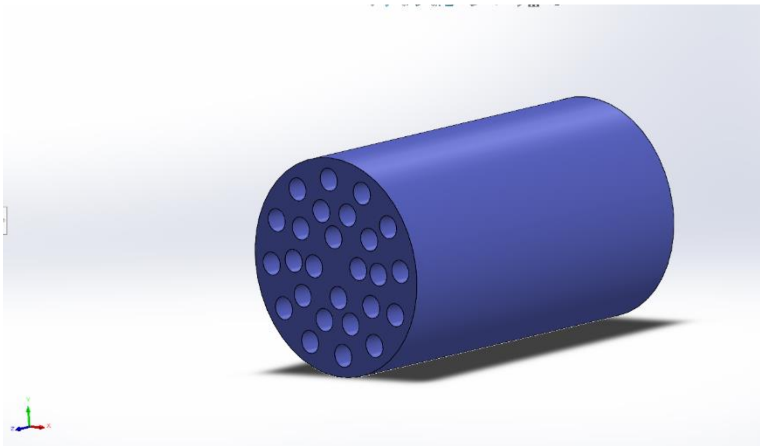

Figure 3.4: CAD model of matrix part.

The orientation of the fiber is continuous within the matrix section and aligned between one another. The arrangement of all fiber is radial figure 3.4, which is 11.20% of the volume is made of glass fiber which is located between another 17.92% of the inner layer and outer layer of the kenaf fiber as shown in table 11. The calculation of the volume fraction is made by utilizing the formula in equation (1) which define as:

$$V=\pi r^2 h \tag{1}$$

where :

V- Volume of the cylinder
r – radius of the cylinder
h - the height of the cylinder