University of Southern Queensland

Faculty of Health, Engineering and Sciences

Influence of fibre length on mechanical properties of natural and synthetic fibres reinforced epoxy composites

Dissertation submitted by

Yaqoup Albahseer

[redacted]

In fulfilment of the requirements of

Course ENG4111/4112 – Research Project

Towards the degree of

Bachelor of Engineering (Mechanical)

Abstract

In this project, a comparative investigation will be carried out to study the possibility of using natural fibres practically jute fibres as substitute to synthetic fibres (glass). Epoxy composites will be fabricated incorporate with the jute fibres and glass fibres. Different fibre lengths will be considered (5mm, 10 mm, 15mm, and 20 mm). Tensile characteristics of bother composites will be determined. Fracture behaviour will be examined using scanning electron microscopy. The findings will be given in next semester.

Acknowledgments

Firstly, I would like to thank God for his spiritual support. My thanks is for the family and friends. I appreciate my supervisor for his guidance. Moreover, I would like to thank the University of Southern Queensland for the facility support.

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ENG4111/ENG4112 Research Project

Limitations of Use

Certification

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

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Chapter 1 Introduction

1.1 Introduction

Academics researchers have strong interest in replacing synthetic materials with bio-materials to suit the governments and environment regulation especially in the developed countries such as Australia as reported. Recently, Nong and Siriwardana (2017) I reported that Australia's main climate change policy transferred from carbon tax to the Direct Action Plan (DAP) owing to achieve emissions target of 5% below the 2000 emissions level by 2020 according to the United Nation Framework Convention on Climate Change, 2014a. Appendix I - Quantified economy-wide emissions targets for 2020,(Change, 2015). This boosts the needs for alternative materials which can manufactured, produced and disposed environmentally friendly. Also, industries are looking for produced which can reduce their emissions towards the government's requirements and reduce the cost of products.

Industrial and academics sectors are working closely to resolve some of the raised issues in the above paragraph. There are several works have been done to develop new eco-friendly products; however, they are not fully commercialised yet due to the lack of deep information, policies and protocols. Despite of that, academics are engaged with industries to identify the suitable materials which can assist both the industries and the government sectors. Academically, attempts of using bio-materials are going on in large scale. Moreover, there are many reports have been published to determine the suitability of the biomaterials for various design parts which includes biopolymers, bio-reinforcements, recycle and waste materials ….etc. However, there are still needs for further understanding of these materials in different design aspects as reported recently by many researchers such as (Abanto et al., 2017; Castegnaro et al., 2017; Giorgio, Andreaus, dell'Isola, & Lekszycki, 2017).

This motivates me to study the natural fibres as alternative to synthetic fibres in composite materials. Fibre lengths found to be very important element in composites design as mentioned recently by (Khanlou, Woodfield, Summerscales, & Hall, 2017; Starý, Krückel, Weck, & Schubert, 2013). Accordingly, I would like to study the influence of the fibres length on the mechanical properties of composites. Epoxy on the other hand, is very good polymers which has very good properties among others, (Karimi & Ramezanzadeh, 2017; Nair, Kuo, Chen, & Yan, 2017). I selected the jute fibres as reinforcements since there are many works are going on and it has very good properties month other natural fibres, (Arfaoui, Dolez, Dubé, & David, 2017; Sathishkumar, Suresh, Nagamadhu, & Krishna, 2017).

1.2 objectives

The aim of the project is to investigate the influence of jute fibres and glass fibres lengths on the tensile, compressive and hardness properties of epoxy composites this includes the sub-objects of

- Fabricate jute fibres and glass fibres in different lengths and Fabricate the composites of jute/glass fibre reinforced epoxy composites
- To determine the tensile properties of the prepared composites
- To examine the fractured surface to identify the failure mechanism

1.3 Outcomes

At this stage I can't give any outcomes unless the project finished will continue this next semester

1.4. Report organization

At his stage, the report is made of three chapters which include the introduction, literature review and part of the methodology. The timeline of the work is given in table 1.1.

Table 1. 1 Project timeline

Task \month	March 17	April 17	May 17	June 17	July 17	August 17	Sep. 17
Establish the background							
Prepared the fibres at different lengths							
Fabrication of the composites							
Conduct experiential work							
Analysis of the data							
Writing of the report							

CHAPTER 2

LITERATURE REVIEW AND BACKGROUNDS

2.1 INTRODUCTION

This chapter covers the literature review on the composites materials and address the current issues related to the material science.

2..2 Composite materials

Composite materials can be defined as a material that consist more than one materials. Composites is build up to improve the characteristics of the individual materials. There are thousands of composites but generally can be divided into metal and polymer composites which are the common used. Currently, polymer composites are going very fast and start replacing the metals in different industrial applications, (Volova, Vinnik, Shishatskaya, Markelova, & Zaikov, 2017). Polymer composites have different kinds which generally can be classified intro three as thermosets, thermoplastic and elastomers. In the following section, I would give general introduction to polymer composites followed by recent issues and resolutions.

2.2.1 polymer composites

In component design, pure resins such as epoxies and polyesters cannot be used due to their limitation for the manufacture of structures because pure resign properties are not very good to be a good as most metals, (Mazumdar, 2001). Polymer composites is made of a type of polymer with the addition of reinforcements. Theses reinforcement can be fibres, particles, or fibres, (Friedrich, Fakirov, & Zhang, 2005). Jayaram

(2017) describes the polymer composites in details and showed the classification in figure 2.1.

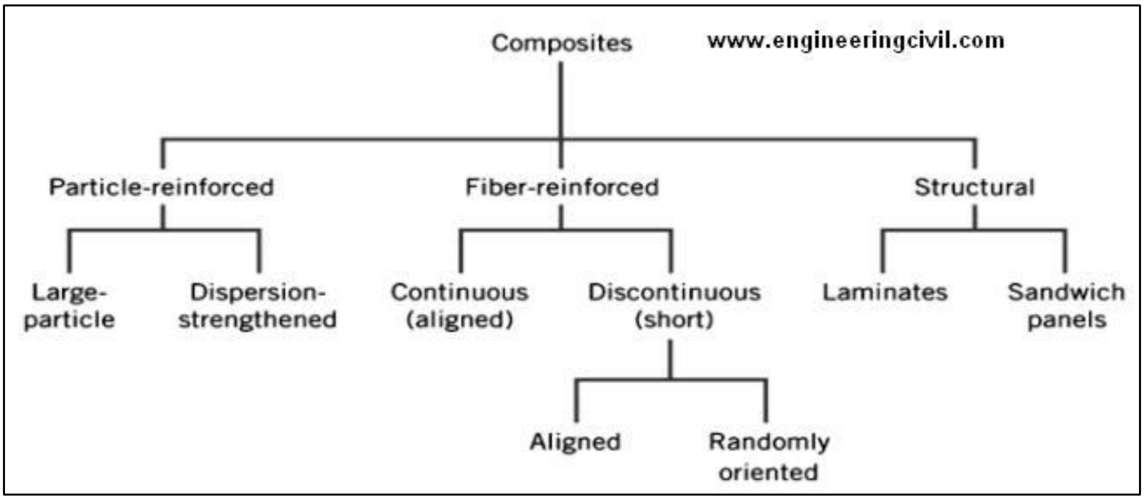
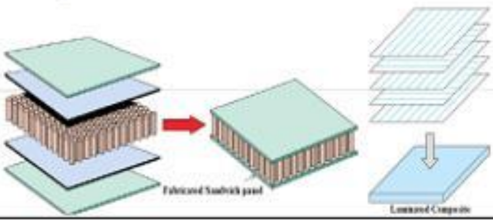


Figure 2. 1 classification of polymeric composites by (Jayaram), 2017.

In the http://www.engineeringcivil.com (7-May 217), the types of composites with examples are given and extracted and shown in Table 2.1. The reinforcement can be particles such as the wood or even the sand which can assist the polymer to improve some of its bad properties such as the brittleness. However, there is always limitation with regards of using the particles since the force transfer from the resin to the particle under loading conditions is not that good as reported by Wetzel, Haupert, and Zhang (2003). Also, the particles always aggregate in the composites and not well distributed. The homogeneity of the composites is not easy to control when the particles added to the composites, (Fu, Feng, Lauke, & Mai, 2008). Sandwich composites is very common in civil applications and structural components since they can bear intermediate loading conditions. Manufacturing them is not that difficult. However, the limitation is the large scale of the composites which limited its application for mechanical components. Also, it required high skill and take long time in fabrications, (Bannister, 2001). Fibre reinforced composites is largely and commercially used in various engineering applications in civil, aerospace, mechanical …etc, (Mallick, 2007). Since the project is focusing on the fibre polymer composites, the next sections will be dedicated for this topic.

Table 2. 1 types of composites extracted from http://www.engineeringcivil.com on the 7th of May 2017.

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

2.2.2 Fibres as reinforcements

Fibre is a type of material that is continuous filaments or in long discrete pieces, (Reviews, 2016). Many of the fibres are usable either for commercial purposes or local usage. There are two types of fibres: natural and synthetic. Natural fibres can be classified into animal, vegetable or inorganic fibres. Animal fibres are composed of protein. Examples of animal fibres include silk, wool, camel, horse and other animals. Vegetable fibres are composed of cellulose and can be classified as short fibres and long fibres. Example of short fibres is cotton and examples of long fibre are flax, hemp, Manila hemp, istle and Spanish moss. The natural inorganic substances include asbestos. Fibres are also obtained from other inorganic substances that can be drawn into threads like metal. The common fibres are glass and carbon. Both types of synthetic fibres have a large input to the economics of different developed countries. Longana, Ong, Yu, and Potter (2016) reported the cost of producing carbon fibres and how much involved in the production line, Figure 2.2. This shows the importance of such fibres and the need for them.

Adekomaya, Jamiru, Sadiku, and Huan (2017) reported the importance of the fibres in their article giving the world production of different fibres type in Figure 2.3. The production of the fibre for different applications required much energy especially with the petroleum production fibres as reported by (Athalye, 2012). Currently the world is facing a real issue of pollution and emission and there is a need to reduce those emission by looking for green materials.

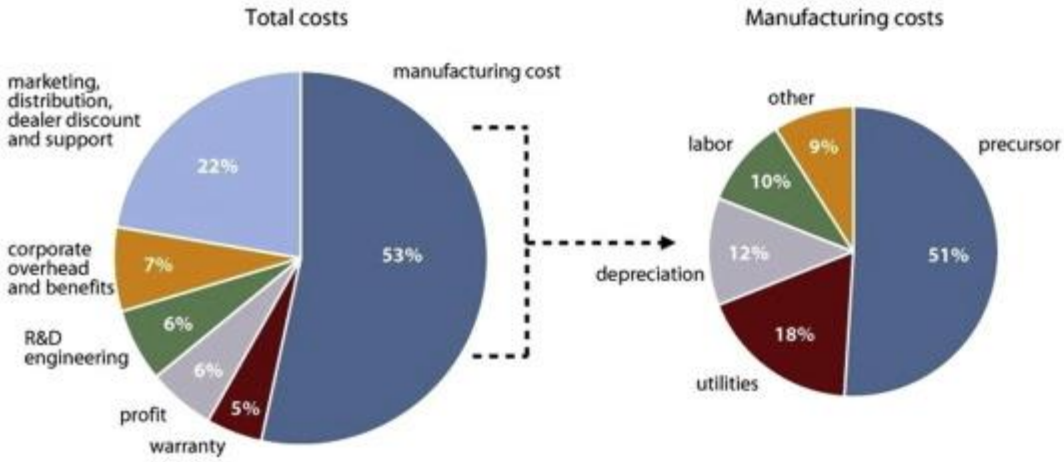


Figure 2. 2 Cost to produce virgin carbon fibre (Longana et al., 2016)

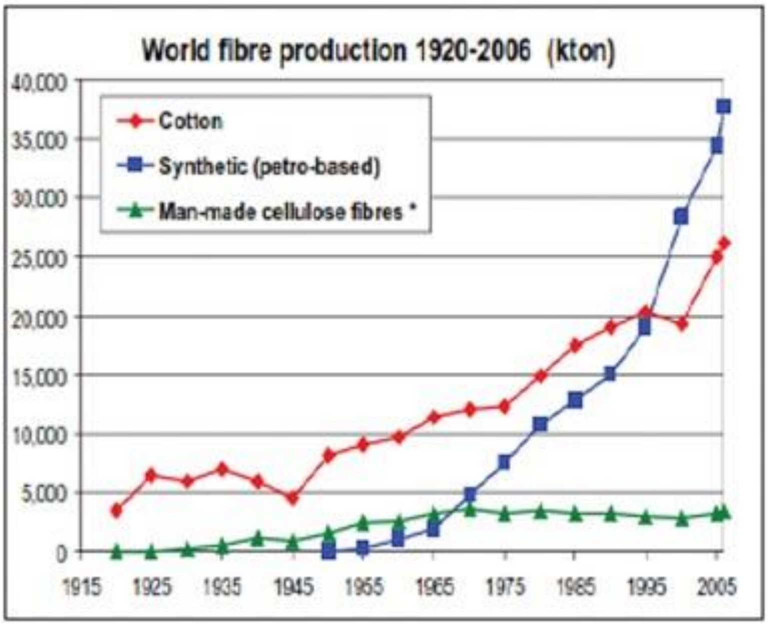


Figure 2. 3 fibre production since 1915 by Adekomaya et al. (2017)

Athalye (2012) determined the energy required for various fibre production as given in Table 2.2. from this table, it is clearly that the energy for synthetic fibre production is relatively high compared to the natural fibres. This attracted many material scientist to attempt using the natural fibres in different resin for composite productions. Natural fibre have been widely explored in many engineering applications due to its comparative advantages regarding recyclability and sustainability, (Cheung, Ho, Lau, Cardona, & Hui, 2009).

Table 2. 2 energy required for fibre production given by Carbon footprint in textile processing

The embodied energy used in production of various fibers	
Fiber	Energy in MJ/Kg of fiber
Cotton	55
Wool	63
Viscose	100
Polypropylene	115
Polyester	125
Acrylic	175
Nylon	250

2.3 Commonly used natural fibres

Nowadays there are many different types of naturally occurring reinforcing fibres being used in the world such as jute, sisal, hemp, ramie, pineapple leaf and flax, to name a few. The use of natural fibres as textile materials began before recorded history for example, the use of hemp fibres originated in Southeast Asia and dates back as far as 4500BC, (Ell, 2008). At this moment, natural fibres can be classified into three distinguished groups: the vegetable, or cellulose based class (cotton, flax, and hemp), the animal or protein based class (wool and silk) and the mineral class (asbestos), (Chawla, 2016). Many plant fibres can be used as reinforcement because the cellulose is fibrous carbohydrate. Cellulose is a hard and stiff substance that can enhance the hardness and stiffness qualities of natural fibres. Fibres with higher cellulose and hemicellulose content have greater tensile strength and impact toughness. Plant fibres can be divided into three categories as reported by Young (1993) and Hodzic and Shanks (2014) as follows:

2.3.1 Leaf Fibre

Leaf fibres are obtained from long, narrow leaves especially from the monocotyledonous plants. Leaf fibre is long but it is hard and coarse. The leaf bundle normally extends to its full length in a sword like leaves and sometimes could be a few feet long. The fibre is located mostly at the leaf under surface. This fibre cannot ordinarily be bleached or chemically treated.

2.3.2 Bast Fibre

Bast fibre is a type of fibre that is on the inner bast tissue (strong and woody) of the plant. The bast portion of the plant is stringy and vascular which consists of ten to forty percent of the mass of stem in the plant and the rest is the all fibrous material. The fraction of the bast depends on the species of plant. Bast fibre is said to have a quality of replacing the conventional is because it has a high strength property. Examples of bast fibre plant are flax, hemp and jute plant. Some of the bast fibre composite have been commercialised and is widely used.

2.3.3 Seed Fibre

Fibre that is extracted from phloem of stem or torn from seed is called seed fibre. The suitable way for extracting this type of fibre is ginning process. Plant or lignocellulose fibres can be divided into different classifications. Chandramohan and Marimuthu

(2011) divided the plant fibres into five categories as wood, stem, leaf, seed and grass as shown in figure 2.4. Stem and lead are the interested fibres since they are not used by human as such others also their mechanical properties in general are good. Chemical composition of natural fibres includes cellulose, hemicellulose, pectin, and lignin, (Saheb & Jog, 1999); and, of each part of the fibres has a property which complete the overall fibre property. fibres contain about 70% cellulose, 15% lignin, and

up to 15% moisture.

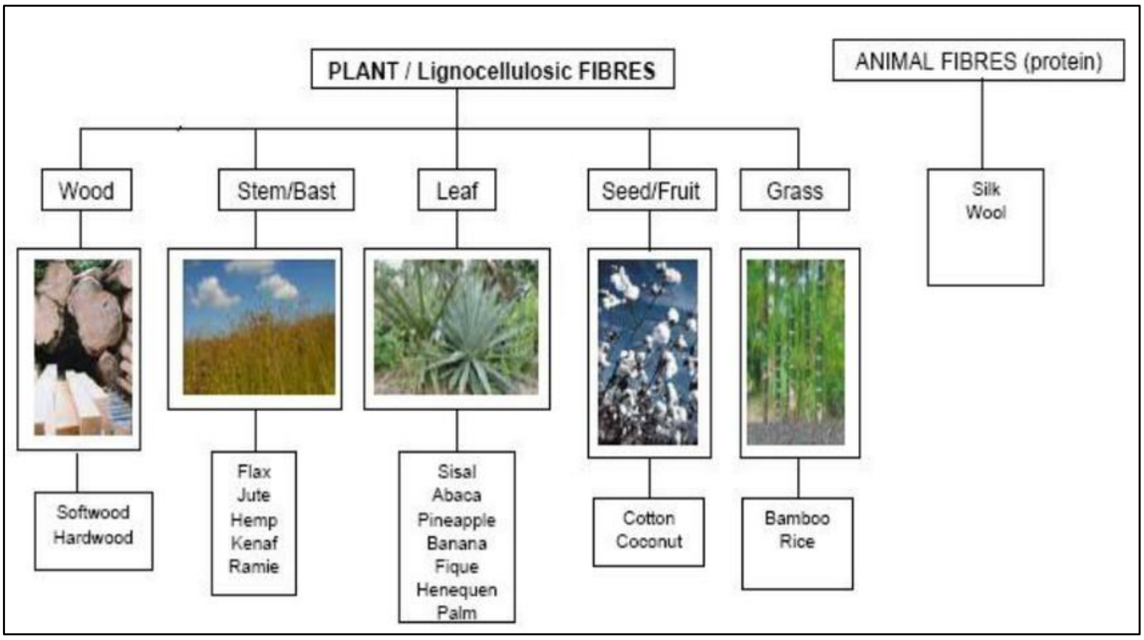


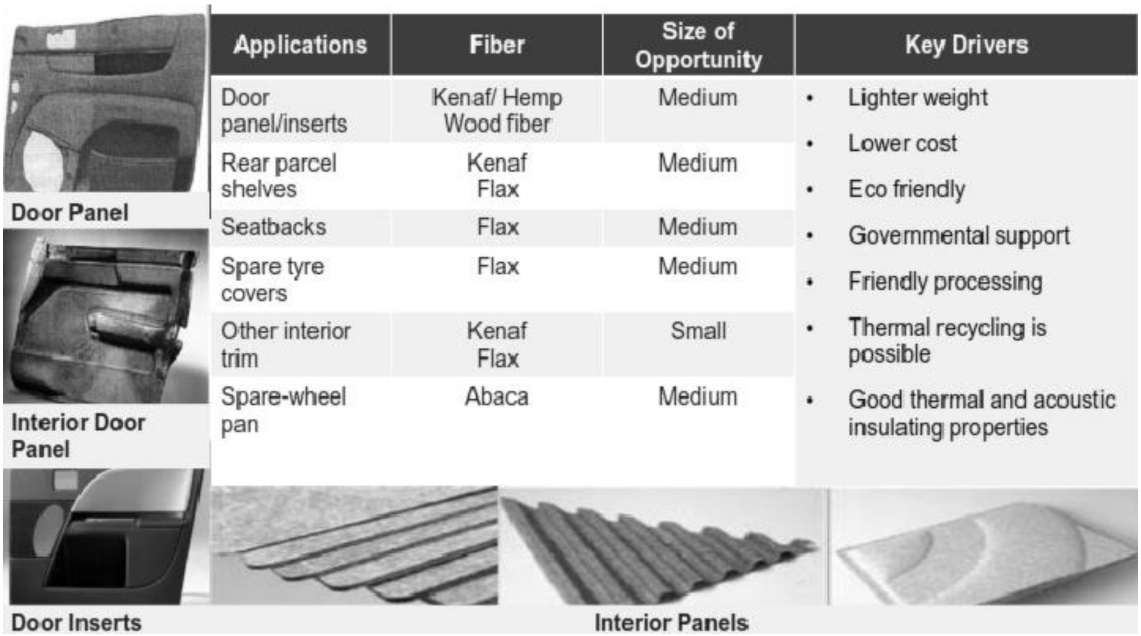
Figure 2. 4 classification of plant fibre as described by (Chandramohan & Marimuthu, 2011).

Table 2. 3 properties of common plan fibres by (Saheb & Jog, 1999).

Fiber	Specific Gravity	Tensile Strength (MPa)	Modulus (GPa)	Specific Modulus
Jute	1.3	393	55	38
Sisal	1.3	510	28	22
Flax	1.5	344	27	50
Sunhemp	1.07	389	35	32
Pineapple	1.56	170	62	40
Glass Fiber-E	2.5	3400	72	28

2.4 Application of Natural Fibres

Nowadays the applications and implementations of the natural fibres are increasingly used in housing construction materials, furniture and automotive parts. Environmental friendly product is getting more demand because the awareness of pollution and other factors that harm the environment have been more and more cultivated among the public. Natural fibre might someday become the compromise to replace syntactic fibre that is not biodegradable. The list below shows some of the natural fibre that frequently used in the world today. In page 73 onwards, in a book by Müssig and Stevens (2010), the application of the natural fibres from industrial aspects are given in details. Some of the current applications of natural fibres are given by Ariadurai (2012), which can include different automotive parts which is given in figure.



Applications	Fiber	Size of Opportunity	Key Drivers
Door panel/inserts	Kenaf/ Hemp Wood fiber	Medium	• Lighter weight • Lower cost • Eco friendly • Governmental support • Friendly processing • Thermal recycling is possible • Good thermal and acoustic insulating properties
Rear parcel shelves	Kenaf Flax	Medium	
Seatbacks	Flax	Medium	
Spare tyre covers	Flax	Medium	
Other interior trim	Kenaf Flax	Small	
Spare-wheel pan	Abaca	Medium	

Figure 2. 5 applications of natural fibres in automotive by Ariadurai (2012).

2.3 CHARACTERISTICS OF NATURAL FIBRES

2.3.1 ADVANTAGES AND DRAWBACKS OF NATURAL FIBRES

The reasons that make natural fibre so special and usable are its ability of biodegradable and recyclable (environmental friendly), (George, Sreekala, & Thomas, 2001) . This helps reducing waste and thus creating more environmental friendly product. That is why the cost of getting this is very cheap, (Porter & Van der Linde, 1995) . In texture making varying of the fibre strips positioning can produce different appearance, which makes the product more attractive. Natural fibre composite product is strong and rigid yet it is waterproof with minimum surface absorption, (Gon, Das, Paul, & Maity, 2012). Natural fibre is well known of its light weight which its lightness and tolerance to high acceleration might be replacing the costly fibreglass as well, (Gon et al., 2012). Furthermore, it is found out that natural fibre is a good thermal insulation and improved the stiffness of the resulting composite, (Bogoeva-Gaceva et al., 2007).

Natural fibers have a nature of hydrophilic. However, the maturity of a plant influences its fibre properties. The properties of the plant fibre also greatly influenced by the weather condition of where it is grown and when it is harvested. In automotive industries, they are cautious of applying natural composites in structural components and other critical parts. Another major drawback is that the fibre could not stand high processing temperature, (Saheb & Jog, 1999). Degradation of quality will occur in the fibre content after a period.

2.5 Parameters influencing the performance of fibre polymer composites

There are many parameters influencing the composite design and performance such as fibre length, fibre orientation and fibre form. The general forms of fibres are presented by (Kutz, 2015) as continuous fibres, discontinuous fibres and whiskers, particles and fabrics or mats. Selection of the fibre forms depends on many consideration such as the application, the size of the components and the amount of the mass products, (Mallick, 2007). In addition, there are many works have been done in this area such as (Morizumi, Kobayashi, & Iwashita, 2017; Mulvihill & Sutcliffe, 2017; Poveda, Ruiz, Cifuentes, Yu, & Zhang, 2017; Scida, Bourmaud, & Baley, 2017). The general findings of those wand previous works concluded that when the fibres the longer the fibres are the better performance for the composites. In some studies, hybrid forms were used, i.e. mixing two forms of fibres in the same composites owing to maintained good properties, (John & Thomas, 2008).

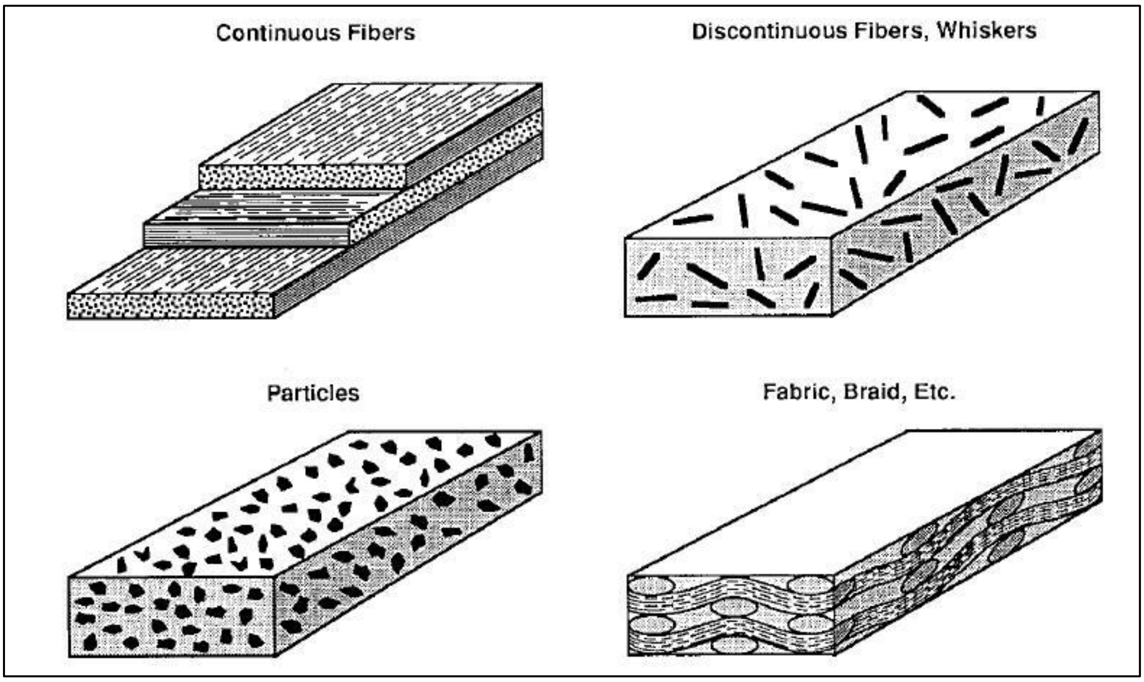


Figure 2. 6 Fibre forms by (Kutz, 2015)

Similar to the effect of the fibre form on the composite performance, fibre orientation is another important aspect which many works have been done for various fibres (Albrecht et al., 2017; Ayadi, Gdhami, Habbal, Mokni, & Yahyaoui, 2015; Hadi & Le, 2014; Yahaya, Sapuan, Jawaid, Leman, & Zainudin, 2016). Barile, Casavola, and Pappalettere (2017) investigated five different configurations of fibre orientations unstitched and Cartesian orientation of woven carbon cloth, stitched laminates and continue carbon tow organised in polar or Cartesian system. It has been found from this work that polar fibres orientation enhanced the through-thickness behaviour of material. In details, failure modes of 13 layers arranged in 0/45/90/-45/0/90/0/45/90/-45/0/90/0 identified by a Cartesian orientation exhibited extensive delamination compare to 6 layer stitched laminates arranged in form of 0/45/90/-45/0/90.

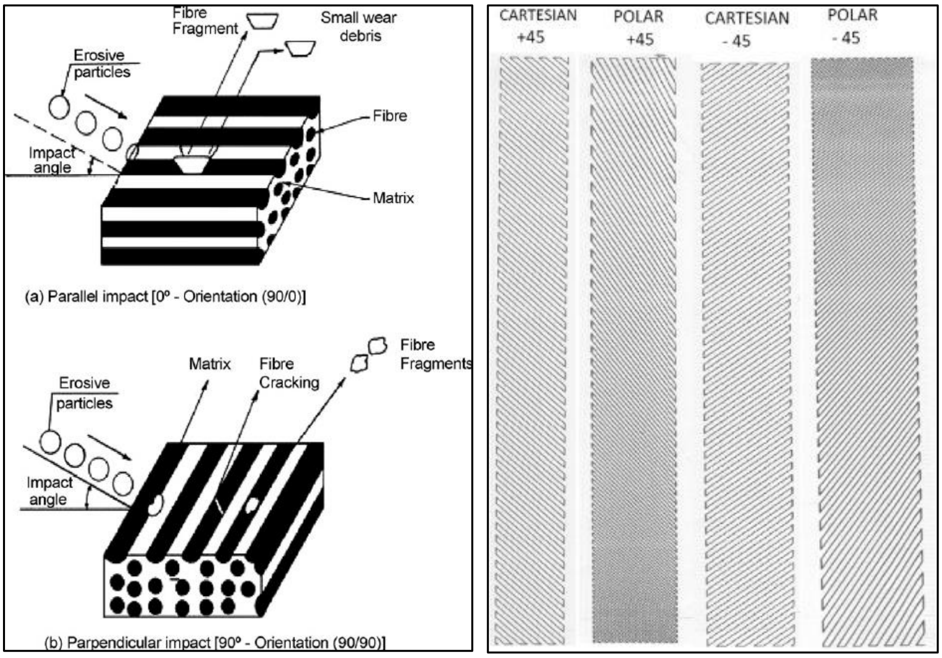


Figure 2. 7 Orientations of fibres represented by Suresh, Harsha, and Ghosh (2009) and Barile et al. (2017)

Fibre length has an important influence on the composite performance and need further understanding to determine the optimum fibre length (critical length) which can carry the load during operating conditions. The critical fibre length is not easy to be calculated numerically, (Achenbach & Zhu, 1989), (Yu, Potter, & Wisnom, 2014), and (Patcharaphun & Mennig, 2017). The following section will be detailing the importance of the fibre length and its influence on different composite properties.

2.5.1 Influence of fibre length on composite performance

From the literature, there are several works have been done to evaluate the composite performance considering the fibre length such as (Bernasconi & Cosmi, 2011; Graupner, Ziegmann, Wilde, Beckmann, & Müssig, 2016; Huang et al.; Ranganathan, Oksman, Nayak, & Sain, 2016; Saba, Paridah, & Jawaid, 2015; Wan & Takahashi, 2016; H.-y. Yu et al., 2014). I would focus on those works since they are the most related and recent works. H.-y. Yu et al. (2014) studied carbon nanotubes with different lengths of less than 4 μ m, 2-3 μ m and 8-20 μ m that were used to reinforce carbon/carbon composites. The results concluded that the improvement has strongly influenced by the orientation and length of the fibres. Small length of fibres and very large length of fibres may have defects such as degradation of fibre -matrix interface which can result in annular cracking. This can lead to a very high out-of-plane compressive strength. It is recommended that the fibres should be straight and long and to reinforce the fibre-matrix interface. Ranganathan et al. (2016) studied the influence of the fibres length of the toughness of hybrid jute fibre reinforce polypropylene; however, the variations in the fibre length was not remarkable since the fibre length carried from 0.9 mm -1.3 mm. The results showed that the increase in the fibre length prevent the crack propagation which led to better performance.

Comprehensive study on the influence of the fibre length has been conducted by Graupner et al. (2016) on different cellulose fibre-reinforced polylactide (PLA) composites. The work considered different fibre content as well. The results were very interested since there is a strong correlation between the fibre diameter and the fibres length to determine the critical fibre length. Some of the results of this work is extracted and given in figure 2.8. Tensile strength of the composites is significantly dependent on the fibre length. The results showed that 3.2 mm fibre length is the optimum and should be considered in the fabrication of the composites. However, since the diameter of the fibres has an equal important element in the consideration, the critical fibre length considering the fibre diameters can be determine in a range from since it is represented in the second figure of 2.8. It can say that the fibre length needs to be greater than the critical length, i.e. small fibre length lowered tensile strength of the composites samples at different content of fibre.

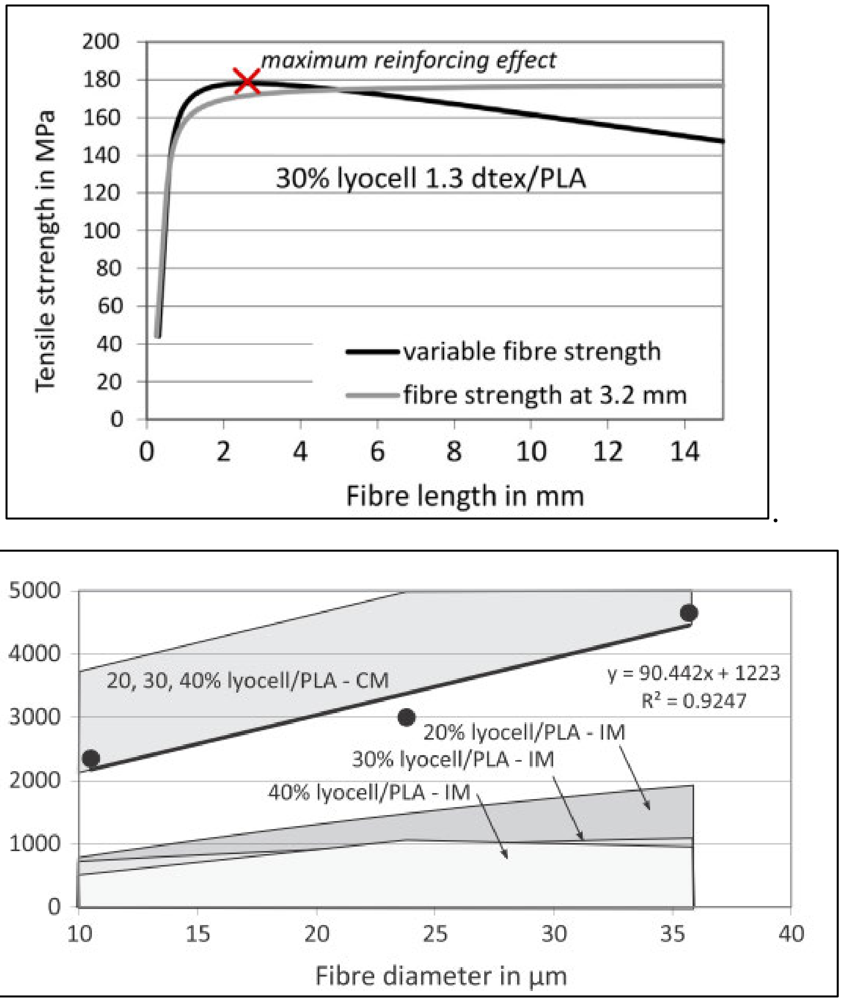


Figure 2. 8 tensile strength of the composites with different fibre length by Graupner et al. (2016)

Tensile and compressive behaviours of chopped carbon fibre tapes reinforced thermoplastics have been investigated by Wan and Takahashi (2016), Figure 2.9. There is no much effect of the fibre length on the compressive properties and the modulus of elasticity of the composites. Fibre length has reasonable influence on the tensile strength of the composites especially at high length of fibres above 12 mm. The results are not clear on how the fibre length affect the tensile since the trend of the tensile strength is not stable and the results were scattered.

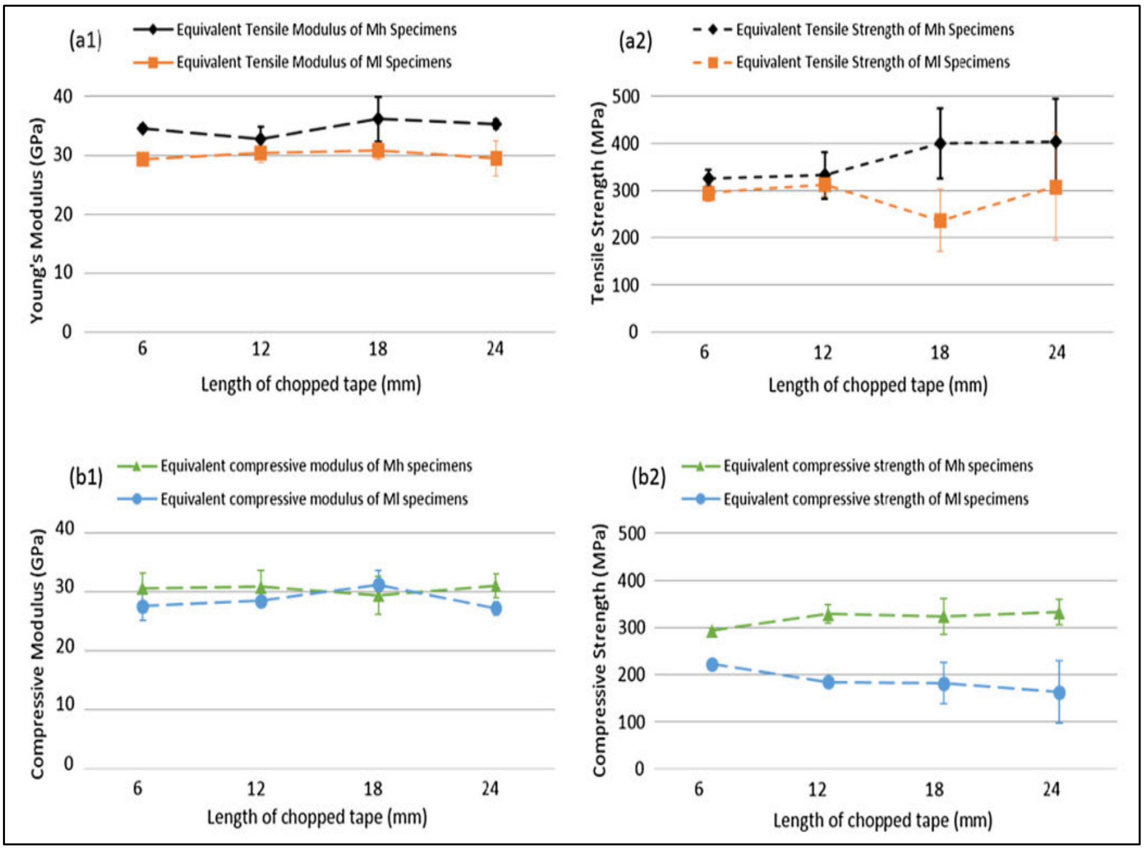


Figure 2. 9 influence of the glass fibre length on the tensile and compressive properties of thermoplastic composites by Wan and Takahashi (2016).

2.6 SUMMARY OF CHAPTER TWO

The summary of this chapter can be; firstly here is a need to study the new development in polymeric composites especially with the green fibre as reinforcement to substitute the synthetic fibres. Secondly, Composite performance is influenced by different parameters such as the form of the fibres, orientations of the fibres, fibre contents and fibre length. This motivates the current study on selecting the jute fibre as natural reinforcements and its length should be considered in this study.

Chapter 3 Research methodology

3.1 Introduction

In this chapter, the fabrication of the composites will be explained to show the difference in the fibre length in the composites. The tensile properties will be experimentally conducted and the experiments will be explained in this chapter as well.

3.2 Material Selection

The epoxy used in the current study is Platinum which is supplied by platinum company in Manly west, QLD, Australia. The mixing ration of this type of epoxy with the hardener is 1:5 by volume as indicated in the specification given in figure 3.1. .

Fig. 3. 1 Platinum epoxy supplied by platinum company in Manly west, QLD, Australia

3.2.1 Fibre preparation

Jute fibres were obtained from Bunning warehouse in a mat form, Figure 3.2. The fibres (Figure 3.3) were extracted from the mat and separated into different fibre length of 5, 10 and 15 mm.

Fig. 3. 2 jute fibre mats purchased from Bunning warehouse.

Fig. 3. 3 Jute fibres

3.2.2 Composite preparation

Figure 3.4 shows the first step in the fabrication the composites which include the preparation of the fibres in different length. There are two types of fibres are used as the jute fibres and the glass fibres, natural and syntactic fibres respectively.

The jute/epoxy composite with different fibre lengths were fabricated in a randomly fibre formats. In the fabrication process a compressive mould press technique is used in which a mould shown in Figure 3.5 fabricated from steel to fabricate the composites. The mixture of the epoxy and the hardener is prepared and then mixed with the selected length of fibre at volume fraction of 35% as recommended by the literature. The block then vacuumed used bag vacuum to get rid of the air in the composites. The block then remains the room for 24 hours for curing. After one day, the block opened and then placed in an oven to be cured at high temperature of 120 ^{o}C.

Fig. 3. 4 prereration of the fibres in different length

Fig. 3. 5 Prepareing the samples and the curing in the oven

3.3 Experimental Procedure

The prepared block was then cut into the tensile dog-bone shape in a dimension given in figure 3.6. In the experiments, universal tensile machine is used to conduct the tensile testing at a loading rate of 2mm/min. each set of fibre length include 3 samples.

The average of the data will be determined and the other properties will be collected. The fracture of the samples will be examined using scanning electron microscopy.

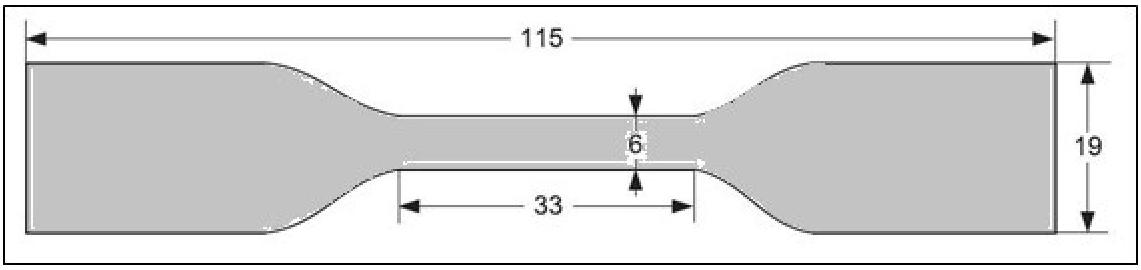


Fig. 3. 6 tensile sample in a dog-bone shape showing the dimensions

Chapter 4 results and discussion

4.1 Tensile behaviour of pure epoxy

Tensile behaviour of pure epoxy is represented in Figure 4.1 displays the stress and strain of the epoxy. The strain at the initial stage was large with very low stress and this is due to the gripping process occurred at the beginning of the test. After the gripping process, the stress began to increase with the increase of the strain in proportional relationship. The increase represents the elastic deformation in the sample. The maximum strength is about 16.5 MPa at strain of 0.05. After the elastic deformation, the failure occurred and there is no plastic deformation can be seen. This is pure brittle behaviour of materials. Oliveira, Margem, Monteiro, and Lopes (2017) reported identical trend of the stress-strain behaviour of pure epoxy which were similar to the polyester behaviour as well. In term of the values, the strength of the epoxy found in the work done by Oliveira et al. (2017) is higher which was about 26 MPa and this is due to the difference in the types of epoxy used.

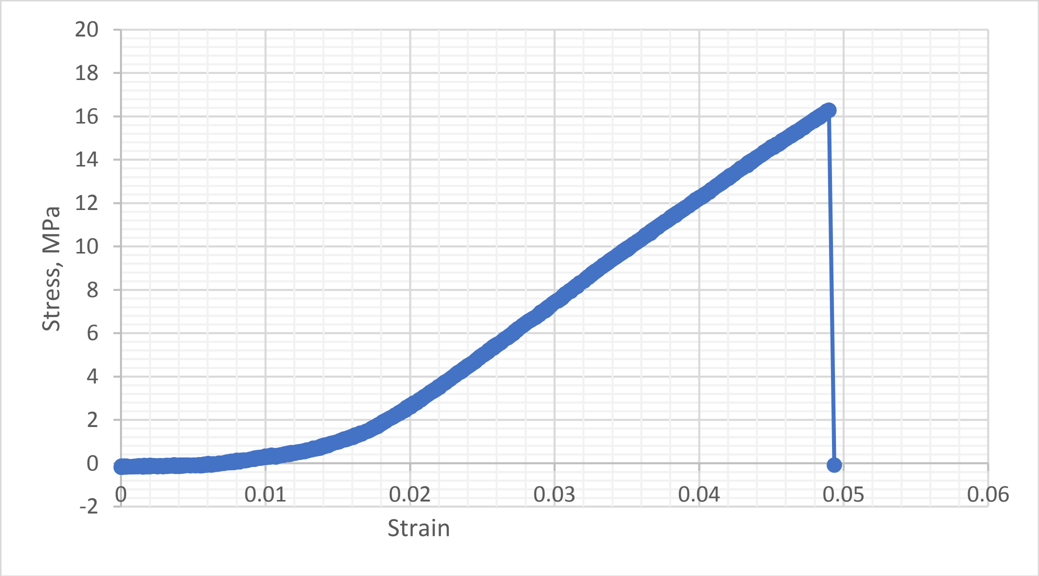


Figure 4. 1 Tensile behaviour of pure epoxy

4.2 Tensile behaviour of glass/epoxy composites

The glass fibre reinforced epoxy composites was fabricated with two different fibre lengths of 5 mm and 10 mm. the tensile results of both samples are presented in Figure 4.2 and 4.3. Both figures show similar trends to the pure epoxy as given in Figure 4.1 since there is a gripping issue at the initial stage and followed by elastic deformation. However, the stress in the composites is much greater than the pure epoxy. In addition, at the last stage of the failure, there is some fluctuation in the stress values. This is due to the pull out or breakage of the fibres at the last stage as suggested by (Dong et al., 2017; Naresh, Shankar, & Velmurugan; Rana, kumre, Rana, & Purohit, 2017). This is in the case of both fibre lengths of 5 mm and 10 mm.

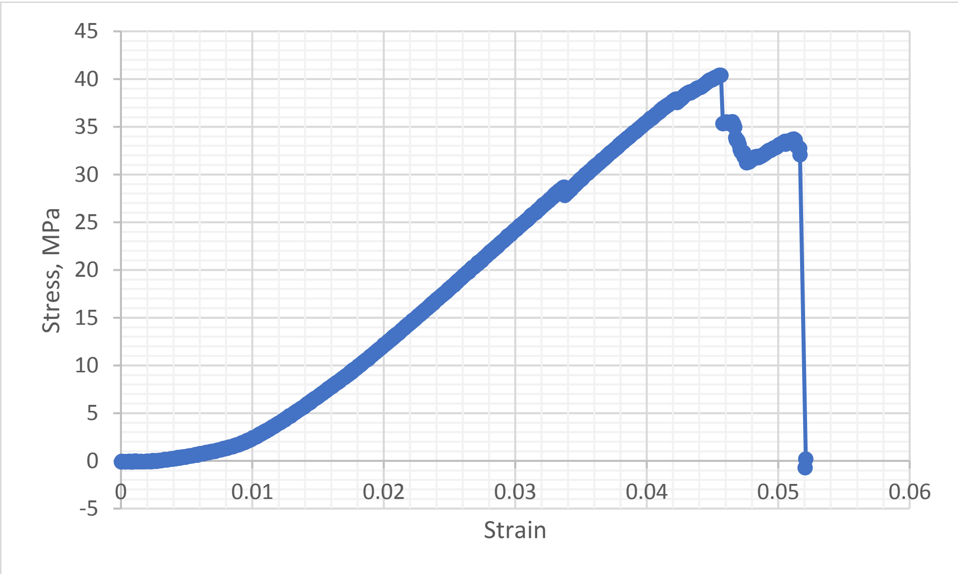


Figure 4. 2 Tensile behaviour of 10 mm glass fibre/ epoxy composites

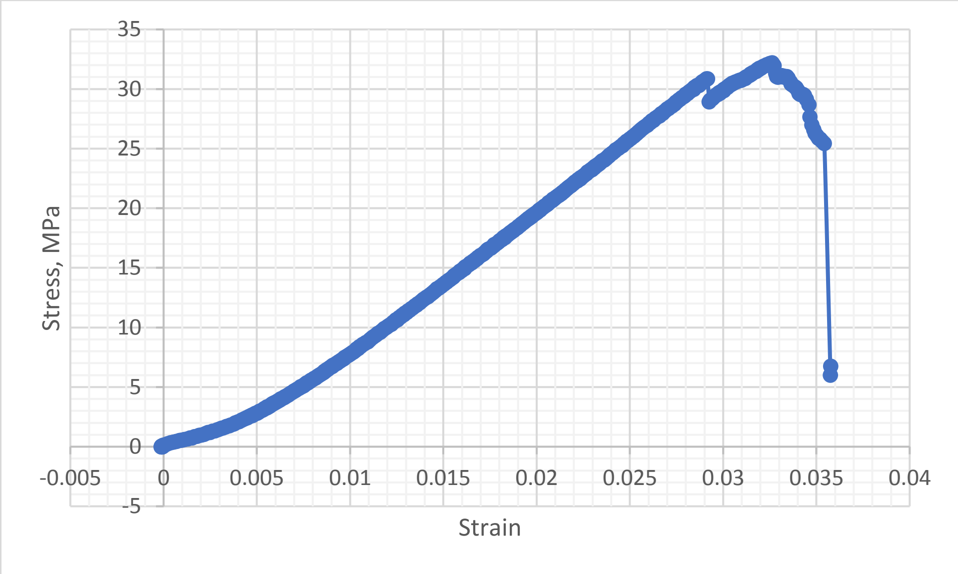


Figure 4. 3 Tensile behaviour of 5 mm glass fibre/ epoxy composites

4.3 Tensile behaviour of jute fibre/ epoxy composites

Tensile behaviour of jute fibre reinforced epoxy composites with different jute fibre length of 5 mm and 10 mm are displayed in Figures 4.4 and 4.5. Both figures show pure brittle nature of the materials which are similar to the pure epoxy given in Figure 4.1. In compare to the glass fibres, the fluctuation in the last stage of the failure, the jute fibres did not show such behaviour. This could be due to the high interfacial adhesion of the jute fibres with the epoxy compared to the glass fibres with the epoxy. The absence of the fluctuation indicates the straight breakage in the whole composites including the fibres as well. Further explanation will be given in the SEM observation. Bisaria, Gupta, Shandilya, and Srivastava (2015) studied the influence of the jute fibre length on the epoxy tensile properties. The fibre length in that work was from 5-20 mm. the value of the maximum stress was about 40 MPa at all the fibres. The type of epoxy used that work is much stronger than the one in this work. In that work the ultimate strength for the epoxy was 40 MPa. Meanwhile in the current study the epoxy strength was only 16 MPa. In that work, there were reduction in the strength of the composites with the addition of all fibre length. However, in the current study there is increase which will be explained further in the coming section.

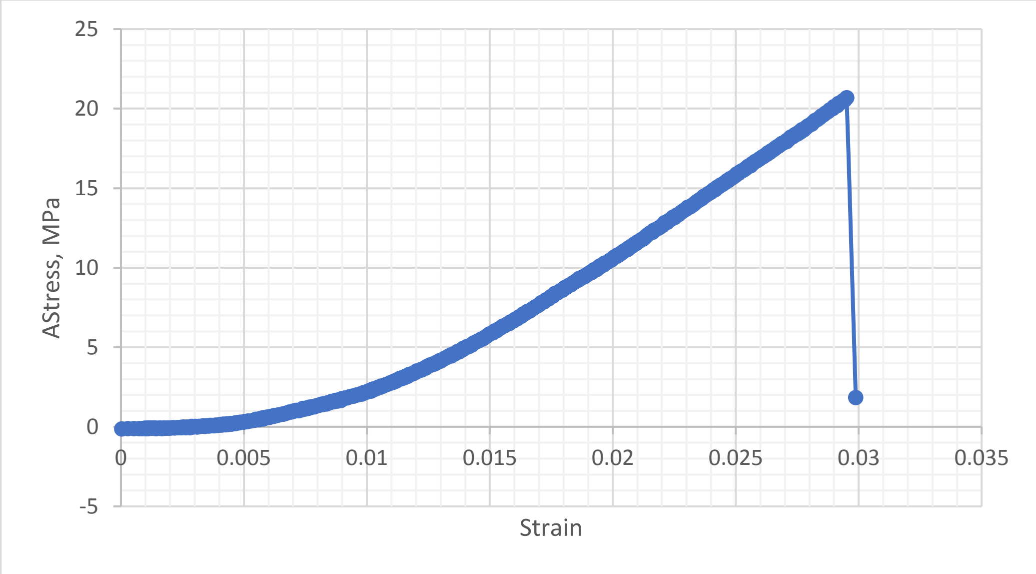


Figure 4. 4 Tensile behaviour of 10 mm jute fibre/ epoxy composites

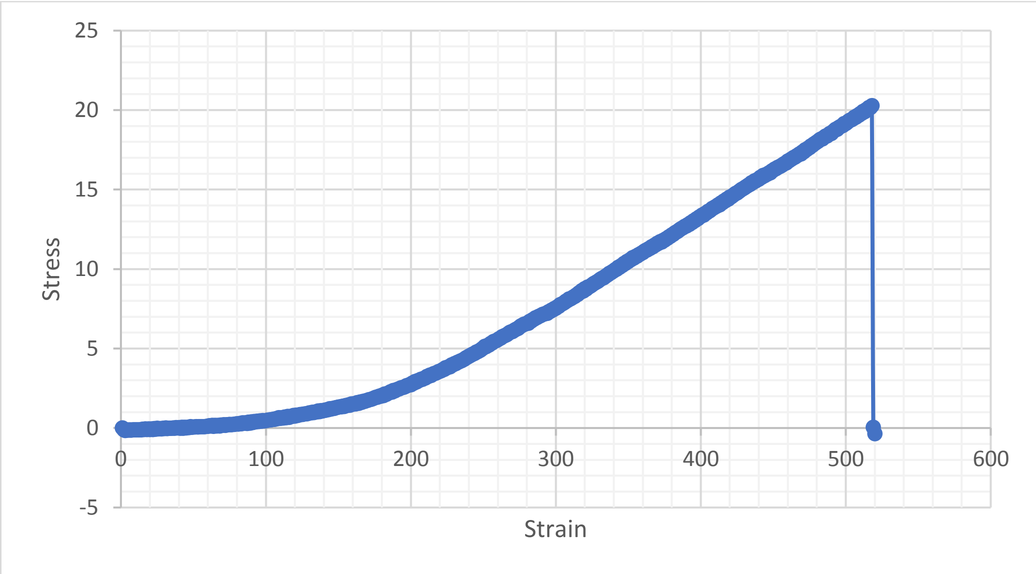


Figure 4. 5 Tensile behaviour of 5 mm jute fibre/ epoxy composites

4.4 Comparison of the data

The maximum strain, ultimate tensile strength and the modules of elasticity of all the tested materials are presented in Figures 4.6- 4.8. Figure 4.6 shows the maximum strain can be seen with the addition of 10 mm glass fibres in the epoxy. The high strain in this composite is due to the pull out of the fibres and the fluctuation in the stress as seen previously. Jute fibres reduces the strain. In other words, there is reduction in the ductility of the composites with the addition of the fibres. This is not clear why since it supposed to increase the stain of the materials with addition of the fibres. On the other hand, this gives a great indication that the fibres managed to carry the load during the tensile condition in the epoxy region. This is evidence in Figure 4.7 and Figure 4.8 which shows the increase in the modulus and the strength of the composites with all the fibres. The fibre length seems to have less effect on the modulus of the jute fibre reinforced epoxy. The 10-mm fibre length jute/ epoxy composites have greater value of modulus which showed that the increase in the fibre length of the jute improves the modulus. However, this is not the case with the glass fibres since it showed the oppose. Bisaria et al. (2015) supports the current results especially the ones for the jute fibre/epoxy composites which indicate the increase in the fibre length increase the modulus and there is no effect on the tensile strength.

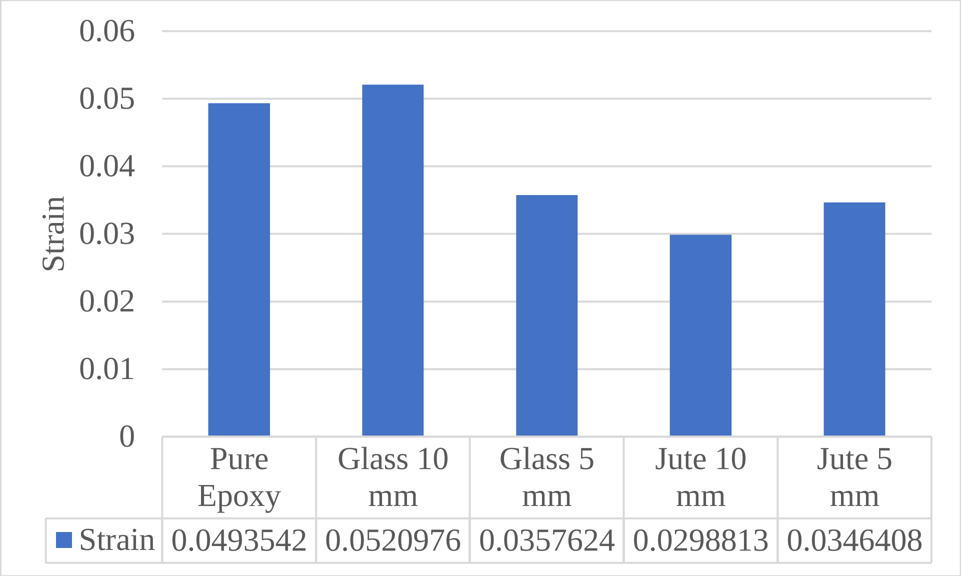


Figure 4. 6 Strain of different epoxy composites

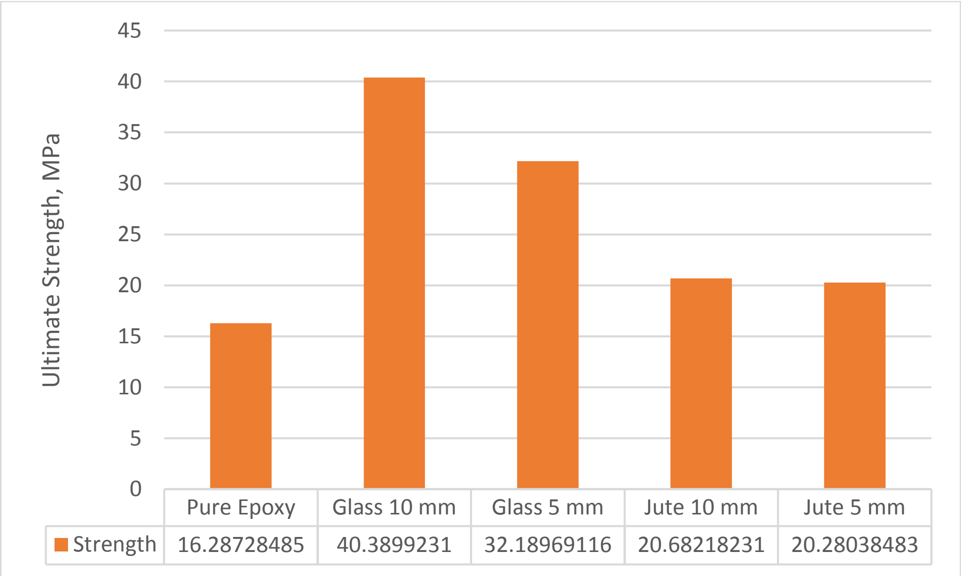


Figure 4. 7 Ultimate Strength of different epoxy composites

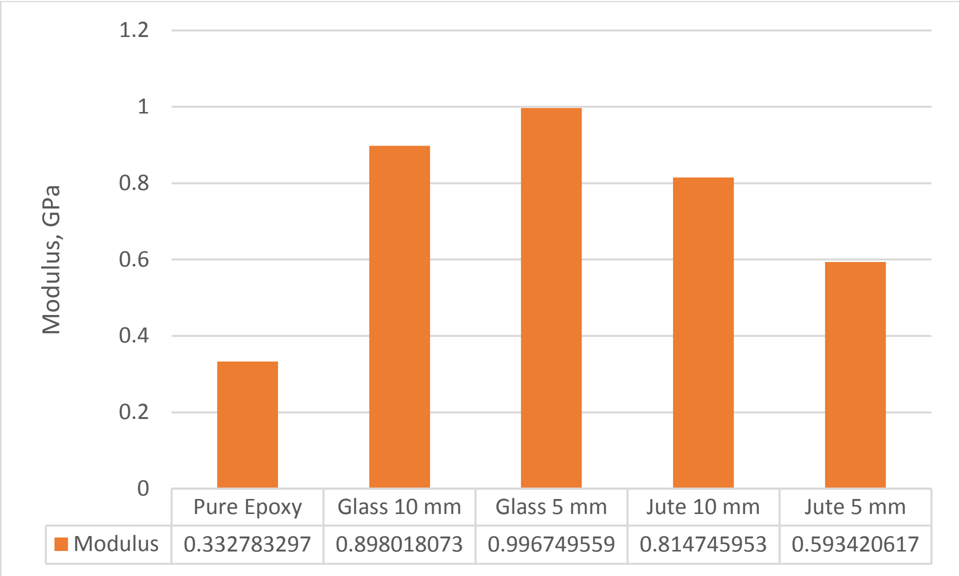


Figure 4. 8 Modulus of different epoxy composites

4.5 SEM observations on the fractured samples

The micrographs of the pure epoxy surface after the tensile failure is given in Figure 4.9. The scanning electron microscopy (SEM) images of pure epoxy show a pure brittle failure since the fracture is look like lip, river-like pattern. Alexopoulos, Paragkamian, Poulin, and Kourkoulis (2017) showed similar failure in that work since the lip, river-like patterns were very clear in the epoxy failed samples.

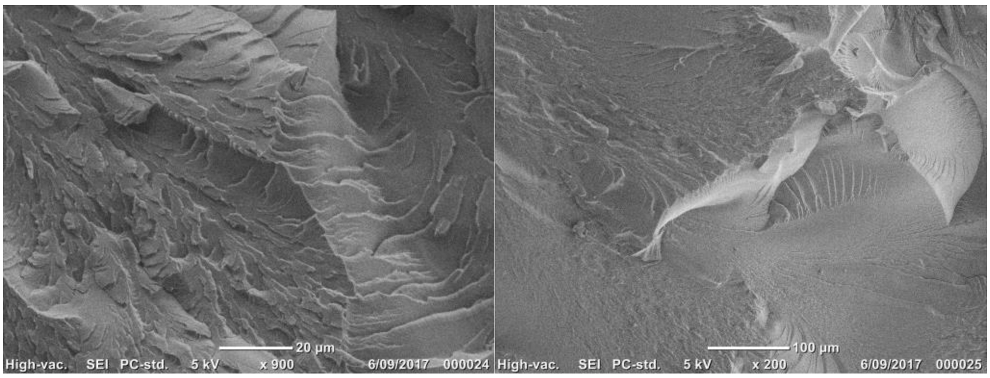


Figure 4. 9 Micrographs of pure epoxy

Figure 4.10 shows the SEMs for the glass/epoxy composites. The micrographs showed a clear pull out mechanism of the glass fibres after the testing which explains the fluctuation in the stress at the last stage of the tensile failure of the sample given in Figure .2 and 4.3. The resin showed a pure brittle nature of failure since the river-like pattern presented. Figure 4.11 displays the images of the jute fibre composites after the tests. The interaction of the fibre with the matrix seems to be very good since there is breakage in the fibres. However, there are some pull-out mechanism and detachment of the fibres after the test. In addition, the broken fibres seem to be empty which indicate that the treatment of the fibres were not sufficient at 6% of NaOH. It is recommended to go high concentration of the chemical treatment. The high concentration of the chemical treatment would allow the epoxy to enter the bundle of the fibres and get better support.

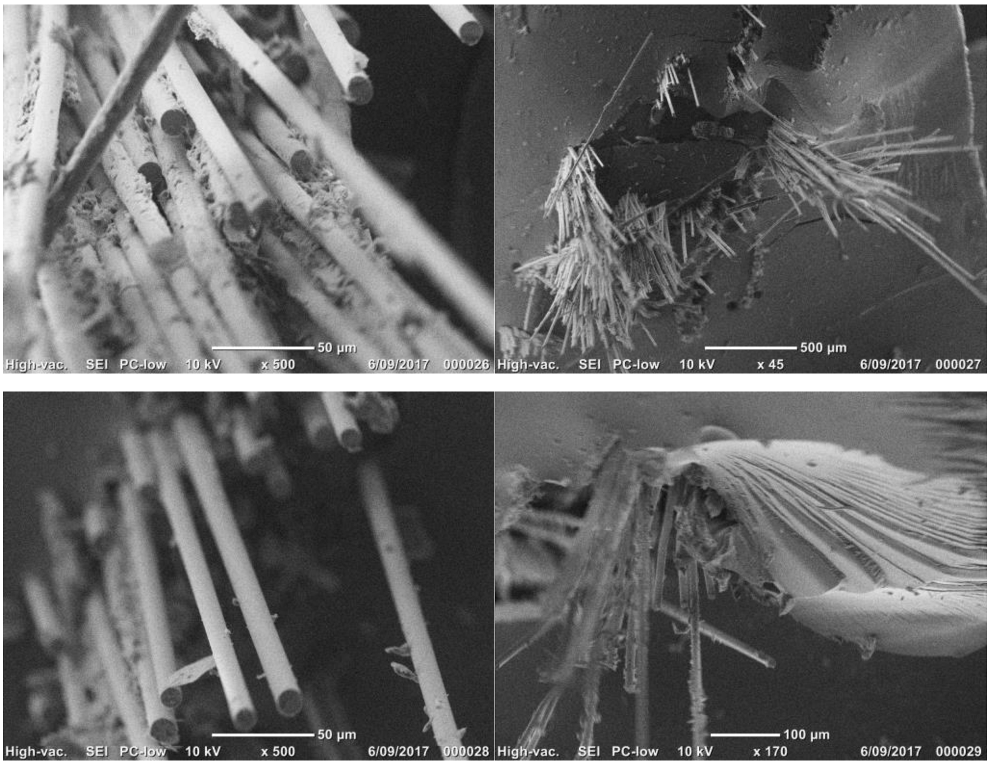


Figure 4. 10 Micrographs of glass/epoxy composites

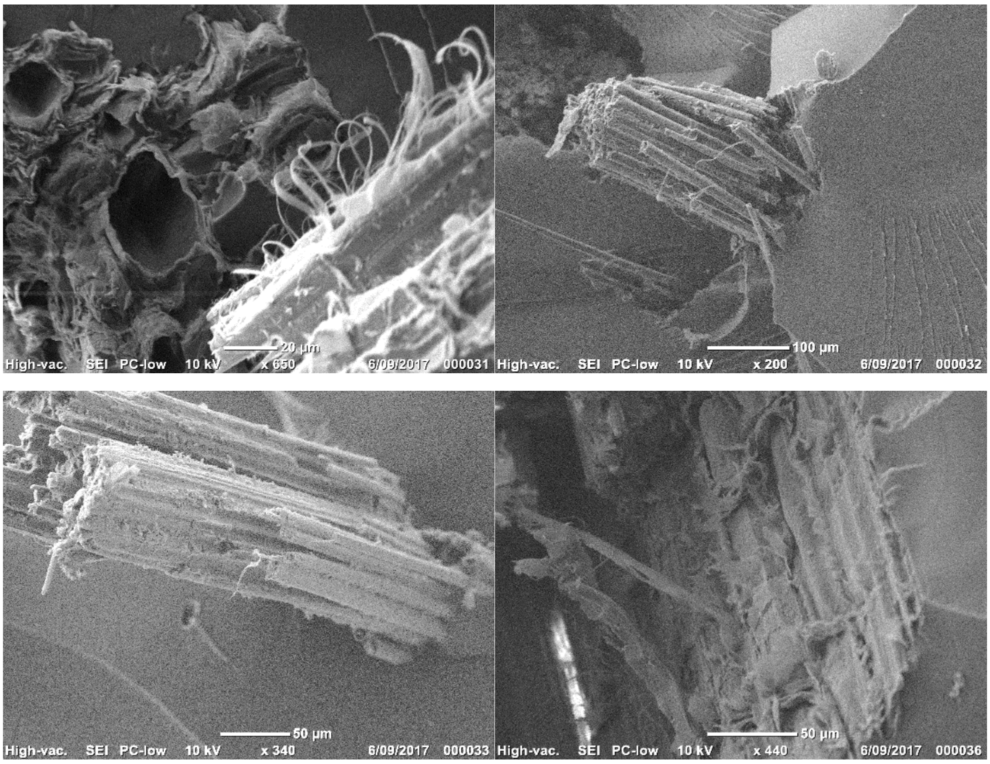


Figure 4. 11 Micrographs of jute/epoxy composites

Chapter 5 conclusions and recommendations

5.1 conclusions

The tensile experimental results on different fibre length of glass and jute fibre reinforced epoxy composites conclude the following points

- The length of the fibres has significant effect on the modulus of the composites especially the glass fibres. The high fibre length gave better support the strength of the epoxy. With case of the jute fibres, there is no much effect of the fibre length on the strength of the epoxy but it impacted on the modulus.
- Jute fibres improved the epoxy tensile properties and there is no remarkable effect of the fibre length on the tensile strength of the epoxy.
- Glass fibres gave better support to the epoxy despite the pull-out failure took place at the end of the test which cased fluctuation in the tensile stress with the high strain at the end of the test.
- SEM observation supported the results since there were pull-out of fibres in the case of the glass fibre/epoxy composites. For the jute fibre reinforced epoxy, there were some breakage in the fibres associated with the detachments and slight pull out.

5.2 recommendations

The results of the work showed some attention needed in the future with regards of the chemical treatment of the fibres. Some work need to identify the optimum chemical treatment concertation for the jute fibres to gain high interfacial adhesion of the fibres with the matrix.

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Appendix A Generic Risk Management Plan

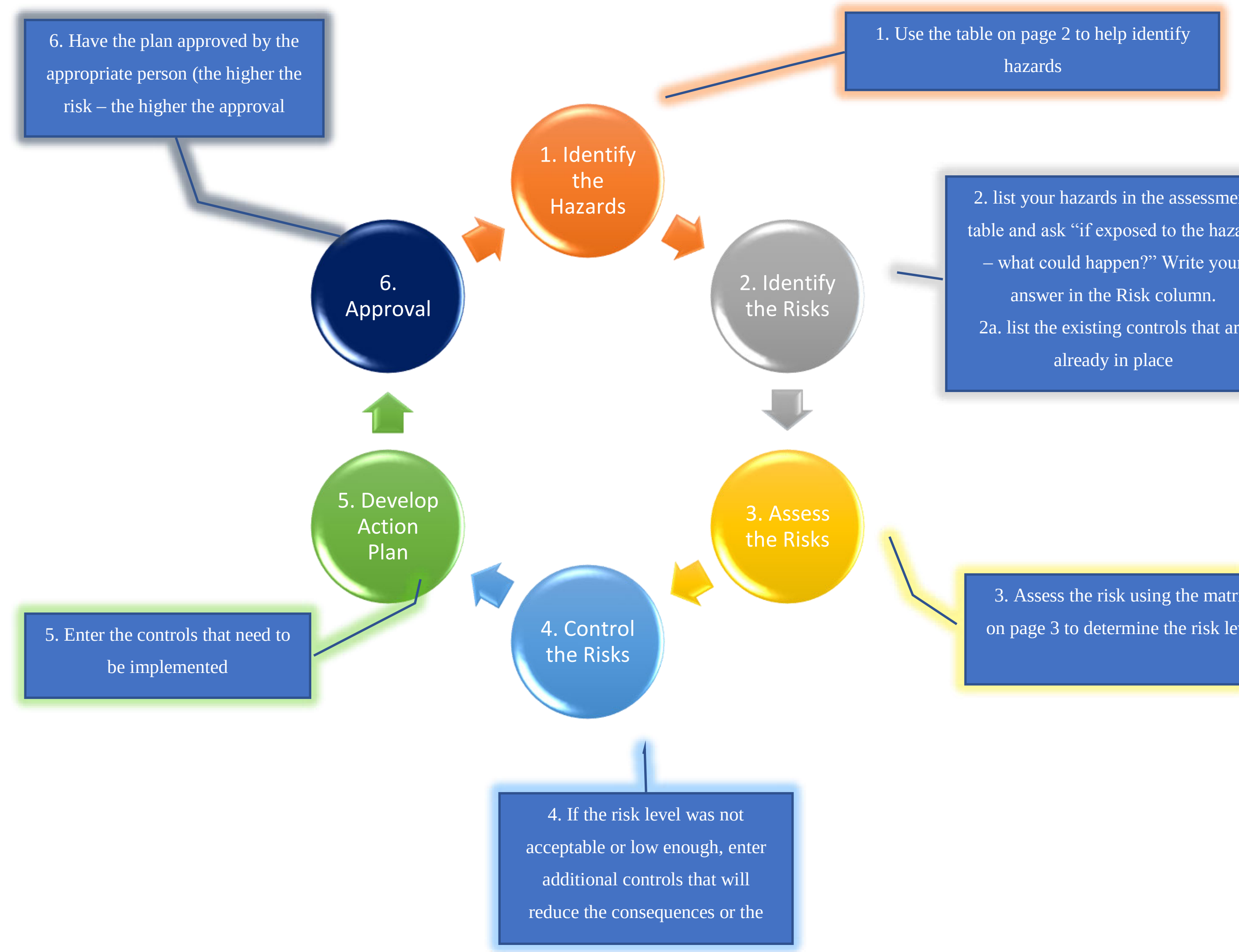
UNIVERSITY OF SOUTHERN QUEENSLAND

University of Southern Queensland

Generic Risk Management Plan

Workplace (Division/Faculty/Section): Z block ground floor corrosion lab		
Assessment No (if applicable):	Assessment Date: 5/5/2017	Review Date: (5 years maximum) 5/5/2017
Context: What is being assessed? Describe the item, job, process, work arrangement, event etc: **Influence of fibre length on mechanical properties of natural and synthetic fibres reinforced epoxy composites**		
Assessment Team – who is conducting the assessment?		
Assessor(s): Dr. Belal Yousif, Others consulted: (eg elected health and safety representative, other personnel exposed to risks) Mr. Mohan Trada		

The Risk Management Process



Step 1 - Identify the hazards (use this table to help identify hazards then list all hazards in the risk table)		
General Work Environment		
☐ Sun exposure	☐ Water (creek, river, beach, dam)	☐ Sound / Noise
☐ Animals / Insects	☐ Storms / Weather/Wind/Lightning	☐ Temperature (heat, cold)
☐ Air Quality	☐ Lighting	☐ Uneven Walking Surface
☐ Trip Hazards	☐ Confined Spaces	☐ Restricted access/egress
☐ Pressure (Diving/Altitude)	☐ Smoke	☐
Other/Details:		
Machinery, Plant and Equipment		
☐ Machinery (fixed plant)	☐ Machinery (portable)	☐ Hand tools
☐ Laser (Class 2 or above)	☐ Elevated work platforms	☐ Traffic Control

☐ Non-powered equipment	☐ Pressure Vessel	☐ Electrical
☐ Vibration	☐ Moving Parts	☐ Acoustic/Noise
☐ Vehicles	☐ Trailers	☐ Hand tools
Other/Details:		
Manual Tasks / Ergonomics		
☐ Manual tasks (repetitive, heavy)	☐ Working at heights	☐ Restricted space
☐ Vibration	☐ Lifting Carrying	☐ Pushing/pulling
☐ Reaching/Overstretching	☐ Repetitive Movement	☐ Bending
☐ Eye strain	☐ Machinery (portable)	☒ Hand tools
Other/Details:		
Biological (e.g. hygiene, disease, infection)		
☐ Human tissue/fluids	☐ Virus / Disease	☐ Food handling
☐ Microbiological	☐ Animal tissue/fluids	☐ Allergenic
Other/Details:		
Chemicals Note: Refer to the label and Safety Data Sheet (SDS) for the classification and management of all chemicals.		
☐ Non-hazardous chemical(s)	☐ 'Hazardous' chemical (Refer to a completed hazardous chemical risk assessment)	
☐ Engineered nanoparticles	☐ Explosives	☐ Gas Cylinders
Name of chemical(s) / Details:		
Critical Incident – resulting in:		
☐ Lockdown	☐ Evacuation	☐ Disruption
☐ Public Image/Adverse Media Issue	☐ Violence	☐ Environmental Issue
Other/Details:		
Radiation		
☐ Ionising radiation	☐ Ultraviolet (UV) radiation	☐ Radio frequency/microwave
☐ infrared (IR) radiation	☐ Laser (class 2 or above)	☐
Other/Details:		
Energy Systems – incident / issues involving:		
☐ Electricity (incl. Mains and Solar)	☐ LPG Gas	☐ Gas / Pressurised containers
Other/Details:		
Facilities / Built Environment		
☐ Buildings and fixtures	☐ Driveway / Paths	☐ Workshops / Work rooms
☐ Playground equipment	☐ Furniture	☐ Swimming pool
Other/Details:		
People issues		
☐ Students	☐ Staff	☐ Visitors / Others
☐ Physical	☐ Psychological / Stress	☐ Contractors
☐ Fatigue	☐ Workload	☐ Organisational Change
☐ Workplace Violence/Bullying	☐ Inexperienced/new personnel	☐
Other/Details:		

Step 1 (cont) Other Hazards / Details (enter other hazards not identified on the table)

Risk Matrix

Eg 1. Enter Consequence

Eg 2. Enter Probability

Eg 3. Find Action

	Consequence				
Probability	**Insignificant** No Injury 0-$5K	**Minor** First Aid $5K-$50K	**Moderate** Med Treatment $50K-$100K	**Major** Serious Injuries $100K-$250K	**Catastrophic** Death More than $250K
Almost Certain 1 in 2	M	H	E	E	E
Likely 1 in 100	M	H	H	E	E
Possible 1 in 1000	L	M	H	H	H
Unlikely 1 in 10 000	L	L	M	M	M
Rare 1 in 1 000 000	L	L	L	L	L

Recommended Action Guide
E=Extreme Risk – Task ***MUST NOT*** proceed
H=High Risk – Special Procedures Required (See USQSafe)
M=Moderate Risk – Risk Management Plan/Work Method Statement Required
L=Low Risk – Use Routine Procedures

Risk register and Analysis

Step 1 (cont)	**Step 2**	**Step 2a**							
Hazards: **From step 1 or more if identified**	**The Risk:** **What can happen if exposed to the hazard with existing controls in place?**	**Existing Controls:** **What are the existing controls that are already in place?**	**Risk Assessment:** **(use the Risk Matrix on p3) Consequence x Probability = Risk Level**			Additional controls: **Enter additional controls if required to reduce the risk level**	**Risk assessment with additional controls:** **(use the Risk Matrix on p3 – ha the consequence or probability changed?)**		
			Consequence	**Probability**	**Risk Level**		**Consequence**	**Probability**	**Risk Leve**
Example									
Working in temperatures over 35^0 C	Heat stress/heat stroke/exhaustion leading to serious personal injury/death	Regular breaks, chilled water available, loose clothing, fatigue management policy.	catastrophic	possible	high	temporary shade shelters, essential tasks only, close supervision, buddy system	catastrophic	unlikely	mod
Mixing of the polymer	Smelly	Wear mask	Minor	Rare	Low	NA	Insignificant	Rare	Low
Aggression of glass fibres	Allergy on the skin	Wear gloves	Minor	Unlikely	Low	NA	Insignificant	Rare	Low
Pinching during placing the sample	Cut	Supervised and place the protector screen during the experiment	Moderate	Rare	Low	NA	Insignificant	Rare	Low
			Insignificant	Unlikely	Low		Minor	Rare	Low

			Minor	Rare	Low		Select a consequence	Select a probability	Select Risk Level
			Select a consequence	Select a probability	Select a Risk Level		Select a consequence	Select a probability	Select Risk Level
			Select a consequence	Select a probability	Select a Risk Level		Select a consequence	Select a probability	Select Risk Level
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			Minor	Rare	Low		Select a consequence	Select a probability	Select Risk Level
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Step 5 – Action Plan (for controls not already in place)			
Control Option	**Resources**	**Person(s) responsible**	**Proposed implementation da**

Step 6 – Approval

Drafter's Comments:

With the personel protective equipments and close supervision all the risk has come to low possibility of gett injured is rare.

Drafter Details:

Name: Signature: Date: 2/03/2017

Assessment Approval: (Extreme or High = VC, Moderate = Cat 4 delegate or above, Low Manager/Supervisor)

I am satisfied that the risks are as low as reasonably practicable and that the resources required will provided.

Name: Belal yousif Signature: BFY Date: 1/5 / 2017

Position Title:

Appendix D Project Resources

Project Resources

1. The supervisor will provide Jute fibres and glass fibres
2. Epoxy resin will be purchase through USQ
3. Preparation of the composites samples will be made at fibre composite centre at USQ
4. All the experimental works will be done at the labs in the first level in Z-block also the SEM observation

Appendix C PROJECT SPECIFICATION

University Of Southern Queensland
Faculty of Health, Engineering and Sciences

ENG4111 Research Project
PROJECT SPECIFICATION

FOR: Yaqoup Albasheer

TOPIC: *Influence of fibre length on the mechanical properties of natural and synthetic fibres reinforced epoxy composites*

SUPERVISOR: Dr B.F. Yousif

PROJECT AIM: the aim of the project is to investigate the influence of jute fibres and glass fibres lengths on the tensile, compressive and hardness properties of epoxy composites

PROGRAMME:

1) Establish the motivation of the work through the literature reading and analysis the previous works .
2) Prepare the jute fibres and glass fibres in different lengths and Fabricate the composites of jute/glass fibre reinforced epoxy composites
3) Conduct the tensile, compressive and hardness testings
4) Examine the fractured surface to identify the failure mechanism