Faculty of Mechanical Engineering

THE IMPACT BEHAVIOUR OF HYBRID KENAF/GLASS FIBRE REINFORCED COMPOSITES

Chan Kin How

Degree of Bachelor of Mechanical Engineering

2018

THE IMPACT BEHAVIOUR OF HYBRID KENAF/GLASS FIBRE REINFORCED COMPOSITES

CHAN KIN HOW

A thesis submitted
in fulfilment of the requirements for the
Bachelor of Mechanical Engineering (with Honours)

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2018

DECLARATION

I declare that his project report entitled "The Impact Behaviour of Hybrid Kenaf/Glass Fibre Reinforced Composites" is the result of my own work except as cited in the references.

Signature	:	………....……..……………………………
Name	:	Chan Kin How
Date	:	...……………..………………………………

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in term of scope and quality for the award of the Bachelor of Mechanical Engineering (with Honours).

Signature	:	………....……..……………………………………
Supervisor's Name	:	Assoc. Prof. Dr. Sivakumar A/L Dhar Malingam
Date	:	...……………..………………………………

ABSTRACT

In this study, woven kenaf/glass reinforced composites have been experimentally investigated. Hybrid composites were fabricated by hot press technique. Hybrid composites consists of woven glass fibre and woven kenaf fibre at symmetrically configuration. Non-hybrid glass/polypropylene and kenaf/polypropylene were also fabricated for comparison purpose. Tensile test was conducted using universal testing machine at speed of 2.00 mm/min. While for the quasi-static penetration test was conducted under crosshead speed of 1.27mm/min with 12.7mm diameter indenter. The low-velocity impact test was conducted by using drop-weight machine to study the impact resistance of the specimens. Failure mode of the tests samples were carefully examined. The results from the study showed that the hybrid samples influenced the impact resistance and tensile properties compared to non-hybrid kenaf and glass reinforced composites. It could be seen that the specific energy absorption for glass hybrid with kenaf was the highest among all test specimens. These finding inspired further exploration of hybrid composite for kenaf/glass reinforced composite for other applications.

ABSTRAK

Dalam Kajian, serat kenaf/kaca tenunan yang diperkuatkan komposit teleh dieksperimen siasatkan. Hibrid komposit telah difabrikasikan oleh Teknik hot press. Hibrid komposit terkandung serat kaca tenunan dan serat kenaf tenunan dalam keadaan konfigurasi yang simetri. Kaca/polipropilena dan kenaf/polipropilena juga difabrikasikan untuk tujuan perbandingan. Ujian tegangan dijalankan dengan universal testing machine dengan kelajuan 2.00mm/min. Ujian kuasi-static penembusan dijalankan di bawah kelajuan silang 1.27mm/min dengan in penderma garis pusat 12.7mm. Ujian halaju rendah hentaman dijalankan dengan mesin drop-weight untuk kaji rintangan hentaman spesimen. Sampel ujian diperiksakan dengan teliti dengan hormatnya mod kegagalan. Semua hasil kajian untuk kajian ini menunjukkan hibrid sampel menpengaruhi ritangan hentaman dan sifat tegangan semasa berbanding dengan bukan hibrid kenaf dan kaca perkuatkan komposit. Ini boleh ditunjukkan oleh penyerapan tenaga tertentu oleh hibrid kaca dengan kenaf adalah tertinggi antara semua spesimen ujian. Pendapatan ini dipercayakan dapat memberi inspirasi untuk exploraition selanjutnya untuk hibrid komposit kenaf/kaca perkuatan komposit dalam aplikasi lain.

ACKNOWLEDGEMENTS

First and foremost, I am greatly thankful to my final year project supervisor, Assoc. Prof. Dr. Sivakumar A/L Dhar Malingam from Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka for his guidance and support on my final year project. The completion of this project could not have been possible without his participation and assistance.

I would also like to thanks to all the technician from Composite Laboratory Faculty of Mechanical Engineering, Material Testing Laboratory Faculty of Mechanical Engineering, and Structure Laboratory Faculty of Mechanical Engineering for their assistance and advices on analysis work.

A special thanks to PhD student Mr. Ng Lin Feng and master student of Faculty of Mechanical Engineering Mr. Kathiravan Subramaniam for sharing their valuable experience and wisdom through out of this project. A big thanks to my friends and family for their support and encouragement all time.

TABLE OF CONTENT

	PAGE
DECLARATION	
APPROVAL	
ABSTRACT	i
ABSTRAK	ii
ACKNOWLEDGEMENTS	iii
TABLE OF CONTENTS	iv
LIST OF TABLES	vi
LIST OF FIGURES	vii
LIST OF ABBREVIATIONS	ix
LIST OF SYMBOLS	x
CHAPTER	
1. INTRODUCTION	1
1.1 Background	1
1.2 Problem Statement	2
1.3 Objective	3
1.4 Scope of Project	3
2. LITERATURE REVIEW	4
2.1 Introduction	4
2.2 Fibre Reinforced Polymer	4
2.3 Hybrid Composite	6
2.3.1 Matrix	8
2.3.2 Reinforcement	9
2.3.2.1 Natural Fibres	10
2.3.2.2 Kenaf Fibres	15
2.3.2.3 Synthetic Fibres	17
2.3.2.4 Glass Fibres	19
2.4 Mechanical Properties	20
2.4.1 Density	21

2.4.2 Tensile Strength 21
2.4.3 Impact Properties 25

3. METHODOLOGY 29
3.1 Introduction 29
3.2 Materials 31
3.2.1 Polypropylene Matrix 31
3.2.2 Fibres 33
3.3 Hybrid Composite Fabrication 33
3.4 Specimen Preparation 34
3.5 Tensile Test 35
3.6 Quasi-static Indentation Test 36
3.7 Low-velocity Impact Test 37

4. DATA AND RESULTS 38
4.1 Volume Fraction 38
4.2 Void Content 40
4.3 Tensile Test 41
4.4 Quasi-static Indentation 43
4.5 Low-Velocity Impact 48
4.6 Damage Mechanism 57

5. CONCLUSION AND RECOMMENDATION 65
5.1 Conclusion 65
5.2 Recommendation 67
REFERENCE 68

LIST OF TABLES

TABLE	TITLE	PAGE
2.1	Types of natural fibres and their respective origins.	11
2.2	Comparison of mechanical properties of some natural fibres and E-glass fibres based on previous studies.	14
2.3	Properties of filled/reinforced polypropylene composite.	17
2.4	Comparison of properties of Natural Fibre and Glass Fibre.	20
3.1	The detail data of the specimen for respective tests according to ASTM.	34
4.1	Volume fraction of each material in the composite.	39
4.2	Measured and theoretical density and void content of each composite.	41
4.3	Tensile properties of composite laminates.	42
4.4	Total energy absorption and maximum force of composite laminates.	46
4.5	Peak energy for each of the composite under low-velocity impact test.	53
4.6	Optical image of all damaged composite for front and rear surface.	58
4.7	Failure surface of the GGG composites after the impact tests.	60
4.8	Failure surface of the GKG composites after the impact tests.	60
4.9	Failure surface of the KGK composites after the impact tests.	61
4.10	Failure surface of the KKK composites after the impact tests.	62

LIST OF FIGURES

FIGURE	TITLE	PAGE
2.1	Classification of natural and synthetic fibres.	10
2.2(a)	Kenaf plant.	16
2.2(b)	woven kenaf fibre.	16
2.3	Classification of man-made Fibres.	18
2.4	Glass fibre volume content (%) versus tensile modulus (GPa) for experimental value and ROM value.	22
2.5	Glass fibre volume content (%) versus the Tensile modulus (GPa) for Experimental value, Theoretical value and Modified theoretical value.	22
2.6	Tensile strength of composite.	24
2.7	The scanned image of damage of different configuration hybrid composite after subjected a 10J impact.	26
2.8	The load–deflection curve of specimen 8 for GC and image of damaged specimen (a) impacted side and non-impacted side, (b) cross-section.	27
2.9	The load–deflection curve of specimen 6 for CG and image of damaged specimen: (a) impacted side and non-impacted side, (b) cross-section.	28
3.1	Flow chart of the methodology.	30
3.2	Stacking sequence of the hybrid composites.	31
3.3(a)	Spherical pellets.	32
3.3(b)	Motorize hydraulic moulding test press machine.	32

3.3(c)	PP sheet fabricated.	32
3.4(a)	Woven Glass Fibre.	33
3.4(b)	Woven Kenaf Fibre.	33
3.5	INSTRON 5969 Universal Testing Machine.	35
3.6	INSTRON 5585 Universal Testing Machine.	36
3.7	INSTRON 9250 Impact Testing Machine.	37
4.1	Ultimate tensile strength and Young Modulus of composite laminates.	42
4.2	Typical force-displacement curve of quasi-static indentation.	43
4.3	Penetration force-displacement curves of composite laminates.	44
4.4	Maximum force and penetration energy of composite laminates.	46
4.5	Specific energy and energy density of composite laminates.	48
4.6	Force-displacement curve of composite laminates (a) GGG and (b) GKG.	50
4.7	Force-displacement curve of composite laminates (a) KGK and (b) KKK.	52
4.8	Force-time curves of composite laminates (a) GGG (b) KGK (c) KGK and (d) KKK.	56
4.9	Figure 4.14: SEM images of composite laminates (a) GGG (b) GKG (c) KGK and (d) KKK.	63

LIST OF ABBEREVATIONS

FRP	Fibre reinforced polymer
PP	Polypropylene
PET	Polyester
PVC	Poly vinyl chloride
ROM	Rule of Mixture
GFRP	Glass fibre reinforced plastic
CFRP	Carbon fibre reinforced plastic
HDPE	High density polyethylene
UTM	Universal testing machine
GKG	Glass/Kenaf/Glass polypropylene hybrid composite
KGK	Kenaf/Glass/Kenaf polypropylene hybrid composite
GGG	Glass/Glass/Glass polypropylene non-hybrid composite
KKK	Kenaf/Kenaf/Kenaf Polypropylene non-hybrid composite
QSI	Quasi-Static Indentation
LVI	Low Velocity Indentation
SEM	Scanning Electron Microscopy

LIST OF SYMBOLS

P_H	-	Properties of hybrid composite of two components
P_1	-	The corresponding property of the first system
P_2	-	The corresponding property of the second system
V_1	-	Relative hybrid volume fraction of the first system
V_2	-	Relative hybrid volume fraction of the first system
ρ	-	Density of the material
m	-	Mass of material
v	-	Volume of material
ρ_c	-	Density of composite
ρ_m	-	Density of matrix
V_m	-	Volume fraction of matrix material
ρ_f	-	Density of fibre
V_f	-	Volume fraction of fibre
v_f	-	Volume of fibre
v_c	-	Volume of composite
V_v	-	Void content
ρ_{ct}	-	Theoretical density of composite
ρ_{cm}	-	Measured density of composite

CHAPTER 1

INTRODUCTION

1.1 Background

Composite is a material where it is made from two or more constituent materials with significantly different physical or chemical properties. The outcome composite has significantly different characteristics of the individual components. The composite is usually widely used in the modern industrial applications as result of its advantages such as low production cost, relatively lightweight, high strength and stiffness. (Faris et al., 2013). Fibre reinforced polymers (FRPs) are composite that made from a mix of fibres and polymer. FRPs are widely used in almost every type of advanced engineering structure from aircraft, helicopter to boat and automobiles, civil infrastructures such as bridges and buildings. Fibre-reinforced polymer composites are also widely applied in modern industry. This attract many researches to carry out study on FRP to develop environmental fibre materials. (Rajesh et al., 2016).

There are two categories of fibre available in the market, synthetic fibres and natural fibres. Synthetic fibres are man-made fibres such as glass, nylon and aramid while natural fibres come from nature, for example, kenaf, jute, hemp and cotton. The hybridization of synthetic fibre and natural fibre can enhance mechanical properties and environmental performance, along with low production costs which are promising for many applications. With a wide understanding of mechanical properties such as indentation behaviour, it can increase significantly the uses of the hybrid composite in a variety of fields. (Yahaya et al., 2014).

There are two major synthetic matrices mainly used in industry, Polypropylene (PP) and Polyester (PET). The properties of PP like relative low density, lightweight to operate, superior tensile properties, good chemical resistance, hydrophobicity, and the relatively inexpensive cost of production has made it popular in use compared to PET (Hafsa, 2016). Also, PP can be reused which significantly reduces the cost of purchasing. Nevertheless, PP has strong hydrophobic and a non-polar properties make it capable to protect the hydrophilic natural fibres (Garkhail et al., 2000).

1.2 **Problem Statement**

In the past few decades, the use of fibre reinforced composites has been growing explosively. Generally, they are in lightweight, making them an ideal choice for many lightweight applications. However, natural fibre reinforced composites often suffer from a lack of toughness. Hence, hybridisation of synthetic fibres and natural fibres can improve most of the mechanical properties and environmental performance in terms of stiffness, strength, ultimate failure strain and impact resistance. The other advantages of hybrid fibre are that they are particularly with low fabrication cost and able to use in many applications. In this study, mechanical properties of hybrid kenaf/glass fibre reinforced polypropylene composites are investigated to maximize their uses.

1.3 Objective

The objectives of this project are as follows:

1. To determine the effect of different woven layup configurations on tensile analysis of hybrid kenaf/glass fibre reinforced composites.
2. To determine the effect of different woven layup configurations on the quasi-static indentation and low-velocity impact behaviour of hybrid kenaf/glass fibre reinforced composites.

1.4 Scope of Project

The test samples in this project are hybrid laminates woven kenaf/glass reinforced composite and the non-hybrid laminates which are glass/polypropylene and kenaf/polypropylene composite. This project focused on the tensile and impact resistance of the laminates. The results obtained are compared to investigate the best laminates. The tests conducted are tensile test, quasi-static indentation and low-velocity impact test. The tests are in accordance to respective ASTM D3039 for tensile test, ASTM D6264 for quasi-static indentation and ASTM D7136 for low-velocity impact.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

A literature review is an important element in research, which provides information on previous studies regards to the research topic. The aims of the literature review are to define the scope of the problem and relate the study to previous studies by comparing and contrasting different author's opinions on an issue.

2.2 Fibre Reinforced Polymer

Fibre reinforced polymer, also known as FRP, is a composite material that made up of polymers matrix embedded with high-strength fibres, for example, glass, carbon and aramid (Groover, 2010). The polymer can be classified into two categories, thermoplastics and thermosets. Thermoplastic materials are currently favour used as matrices in the fabrication of composite. The most typically used thermoplastics are polypropylene (PP), polyethylene (PE), and polyvinyl chloride (PVC); the most utilised thermosets are phenolic, epoxy and polyester resins (Ku et al., 2011).

There are several methods to fabricate fibre reinforced polymers, with tools or a mould. The mould can be divided into concave female mould, male mould or mould that completely enclose the part with a top and bottom mould. The methods which can be used to fabricate FRP are hand layup method (wet/dry), compression molding, filament winding, bladder molding and etc (Sahas et al., 2017)

Fibre reinforced polymer composites are widely used in many applications because of their relatively good mechanical properties. When compared with a metallic material, FRPs have several advantages such as high strength, higher stiffness, better fatigue resistance, lightweight and remarkable designability. The functionality of FRP composites increase dramatically, specifically in weight and environmental crucial structures such as aircrafts, vehicles and wind blades (Xu et al., 2017). Moreover, in automobile field, the weight of the vehicle is one of the huge factors that impede the achievement of sustainable development which is energy saving and environmental care purpose. Also, the rate of carbon dioxide emission from the vehicles has been restricted by emission-reduction standards. Hence, to achieve lighter-weight automobiles, the most predominant method is by replacing the main parts with lighter weight materials. FRP composites are an alternative material as they have high specific modulus and strength especially relatively lightweight compared to the metallic material. Therefore, the automobile industry has introduced the use of FRP composite in for a long time to manufacture vehicles which are environmental-friendly, energy saving and lightweight (Wang et al., 2017). FRP composite have many applications because of the ease of processing, price is low and better mechanical properties. In electronic packaging application, FRP composites can be a substitute for metal materials particularlly the combination of metallic fibre with polymeric matrix is an attractive material (Sakthivel, 2013).

To enhance the performance of FRP for example high impact and tensile strength, high thermal resistance, good interfacial adhesion between reinforcements and matrix, dimensional stability and etc, many studied have been broadly carried out to design better FRP composites (Lee et al., 2017). One of the ways to improve mechanical properties is to introduce reinforcing filler, for example, glass and carbon fibres. These fibres able to improve the mechanical strength up to ten times to fifty times.

The previous study showed that glass or carbon fibre reinforced polymer composites are preferred materials applied in aircraft and aerospace engineering industries as the materials possess characteristics such as high specific strength-to-weight ratio and non-corrosivity can save fuel, especially in the designs of on-road and in-air vehicles (Hung et al., 2017). Zhang stated in the report that glass fibre composite increasingly used to replace steel in the automotive industry. GFRP and CFRP manage to reduce vehicle weight up to 20-35% when using GFRP and 40-60% when using CFRP (Zhang et al., 2012).

2.3 Hybrid Composite

Hybrid composite is a merge of two or more different group of fibres with matrices. Different fibres with their own advantages, hybridization able to take full advantage of the best properties of the constituents and balance out each other fibre deficiency (Sanjay et al., 2017). The fibres can be in categories of natural or artificial fibres. The possible outcomes of hybrid composites are synthetic-synthetic fibres composite, natural-natural fibres composite or both synthetic and natural fibres composite. Hybrid composites have lighter weight and low cost in comparison to the composites with single type of fibre. The disadvantages of non-hybrid composites are over-strength and not-cost-competitive (Hung et al., 2017).

Hybrid composites offer some advantages over non-hybrid fibre reinforced composites (Boopalan et al., 2013). In usual cases, hybridisation is interlaminate and intralaminate. Interlaminate, which is also known as simply laminate, contains depositing layers built from a variety of fibres; intralaminate contains depositing layers entangled within one layer (Almeida et al., 2013).

Hybrid composite materials have wide applications in the field of engineering due to low cost, strength-to-weight ratio and ease of manufacturing. These hybrid composites bring about stiffness, strength and ductility, which cannot be achieved by single fibre reinforced composites. Hybrid composites increase fatigue life, elevate fracture toughness and lower notch sensitivity in a comparison with the single fibre reinforced composites (Srinivas et al., 2012).

By hybridizing with high strength synthetic fibres, the properties of natural fibre reinforced composites can be improved. The formation of hybrid composites involves the interspersion of the two (2) or more varieties of fibres in a common matrix. The significant adjustment to the mechanical properties of the composites is known to be the reason of the incorporation of fibres (man-made or natural) into a polymer (Jawaid, 2011b). Previous studied showed hybridization of lignocellulose and synthetic fibres, for example, glass and carbon fibres able to improve the stiffness, strength as well as moisture resistance of the hybrid composite (Busu et al., 2010).

The strength of the hybrid composites can be affected by several factors such as the properties of fibre, length of the individual fibre, the orientation of fibre, fibre to matrix interface bonding, the aspect ratio of fibre content, extent of intermingling of fibre and arrangement of both the fibres and failure strain of individual fibres. The fibres with high strain compatible able to obtain a maximum hybrid result (Jawaid et al., 2011a).

Rule of Mixture (ROM) Eq. (2.1) can be used to theoretically predict the properties of hybrid composite of two components.

$$P_H = P_1V_1 + P_2V_2 \tag{2.1}$$

Where P_H is the property to be investigated, P_1 is the corresponding property of the first system and P_2 the corresponding property of the second system. V_1 and V_2 are relative hybrid volume fraction of the first and second system. $V_1 + V_2 = 1$ (Sreekala et al. 2002).

2.3.1 Matrix

Matrix is a medium that is used to hold or bind reinforcement together as a composite and at the same time acts as a layer of protection for the reinforcement towards the environmental damage and provide ability to transfer load. The two classes of the matrix are thermoset and thermoplastic which are mainly used in composite applications (Kabir et al., 2012). The common examples of thermoset matrices are unsaturated polyesters, epoxy and phenolics. The common examples of thermoplastic matrices are polypropylenes, polyethylene and elastomers.

There are many reasons to promote the selection of PP as a matrix in the composite fabrication process. The main benefit of PP is their relatively low processing temperature which is especially required in the fabrication process of natural fibre based composites due to the low thermal stability of natural fibres. Most of the natural fibre has an average degradation temperature below 200°C. Due to the limitation of low degradation temperature of natural fibres, thermoplastic with a low processing temperature is preferable to be used as matrix. The melting point of polypropylene is identified through the search of the maximum temperature of a differential scanning calorimetry chart as the melting of polypropylene takes place across a range. Most commercial PP possess levels of crystallinity in the range between 40% and 60%, which are the intermediate level. Isotatic polypropylene has a melting point of perfectly 171°C while commercial isotactic polypropylene has a melting point in the range between 160°C to 166°C in dependence on atactic material and crystallinity (Quazi et al., 2011).

Apart from that, polypropylene also offers the advantages such as low price, high toughness, low density, relatively high thermal stability, high chemical resistance and recyclable (Reis et al., 2007**).** Polypropylene has a number of beneficial characteristics which enhance the application, such as high heat distortion temperature, transparency, flame resistance and dimensional stability. As a matrix material, PP provides attractive qualities for the manufacture of composites. PP is also very appropriate for filling, reinforcing and blending. One of the most favourable methods to produce natural-synthetic polymer composites is polypropylene with natural fibrous polymers (Quazi et al., 2011).

Polypropylene polymer can be made by polymerizing propylene molecules. There are three major sources of polypropylene. The first source of propylene monomer is sub-product from the steam-cracking process of naphtha. Naphtha is a valuable fraction of crude oil. Secondly, propylene monomer can be obtained from gasoline refining process and lastly, which is the recent new process, propylene monomer is produced by dehydrogenated propane. (Quazi et al., 2011).

2.3.2 REINFORCEMENT

The reinforcements for hybrid composite are usually from fibre group. Fibre which has superior mechanical properties able to withstand a load in the fibre reinforced polymers matrix composites. The two classes of fibres which are available in the market are natural and synthetic fibres. Figure 2.1 shows the classification of natural fibres and synthetic fibres (Jawaid, M., 2011a).

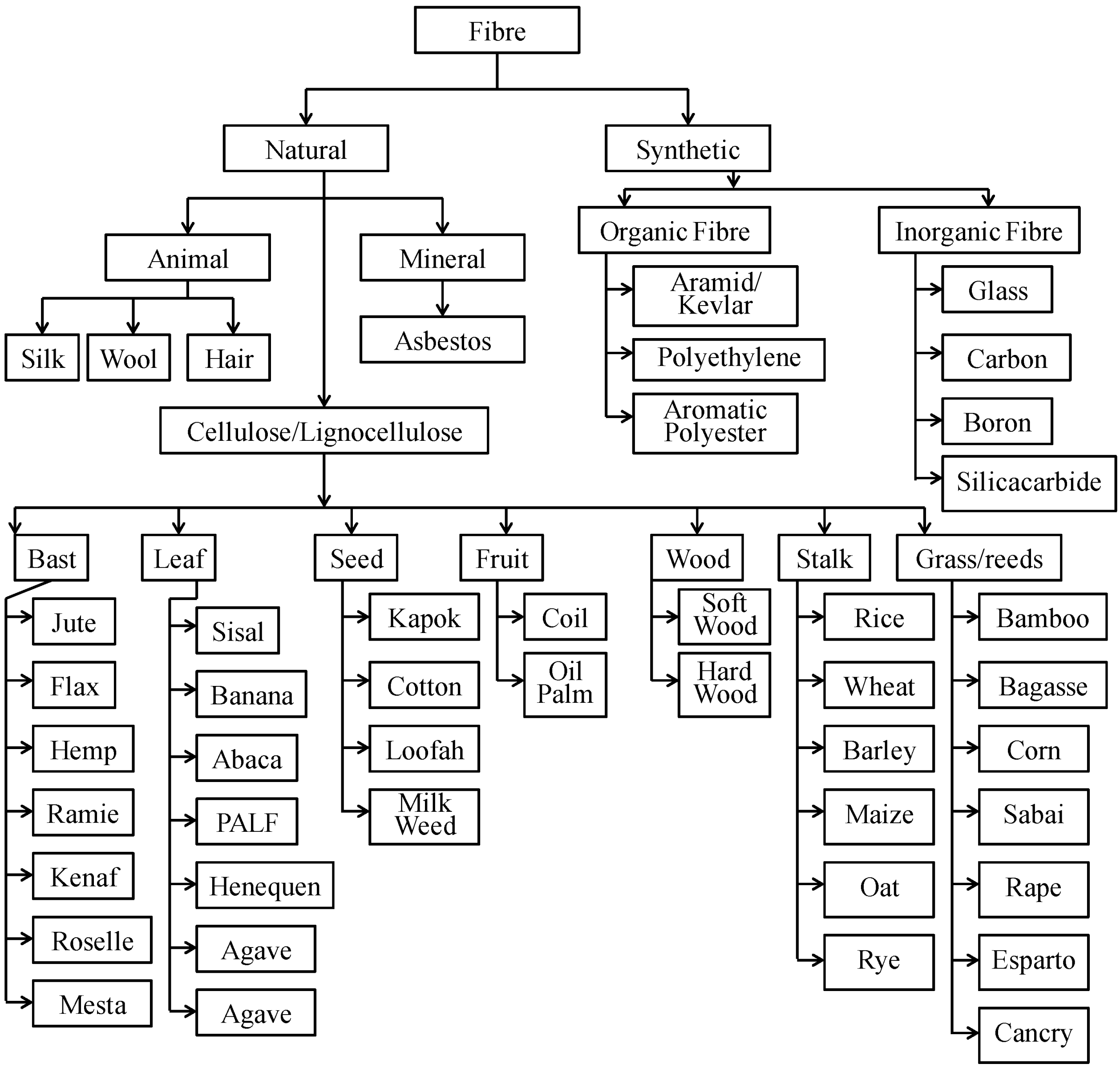

Figure 2.1: Classification of natural and synthetic fibres (Jawaid, M., 2011a).

2.3.2.1 Natural Fibres

In the recent decades, sustainable development of environmental friendly products is the huge factor in the selection of material for engineering applications. Natural fibres which have a great capability of recycling successfully attract the attention of researchers and scientists over conventional glass and carbon fibres. Natural fibres act as an alternative reinforcement in polymer composites. (Malkapuram et al., 2008).