THEORETICAL PREDICTION OF RECLAIMED CARBON DUST FILLER ON MECHANICAL PROPERTIES OF SILK FABRIC COMPOSITE

This report is submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Hons.)

by

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Date : 8 February 2021

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

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ABSTRAK

Gentian semula jadi adalah pengganti gentian kejuruteraan yang telah digunakan secara meluas dalam pelbagai aplikasi industri dan komersial kerana gentian itu ada potensi tinggi untuk meningkatkan produk mereka. Ini disebabkan oleh sifat gentian semula jadi seperti rendah kos, ringan, kebaharuan dan mesra alam berbanding dengan gentian sintetik. Di antara gentian semula jadi, sutera adalah gentian semula jadi dari haiwan yang banyak digunakan kerana aplikasinya yang tanpa had dan juga kerana ianya kuat, gentian halus yang panjang dan mempunyai sifat mekanikal yang baik. Di antara masalah yang terdapat dalam kajian ini ialah sangat jarang sutera digunakan sebagai bahan pengukuhan oleh kerana kos yang agak tinggi dan kurang maklumat sifat mekanikal mengenainya. Dalam kajian ini keupayaan serbuk karbon sebagai pengisian terhadap sifat mekanikal sutera komposit disiasat. Gabungan gentian ini dengan pengisi akan menawarkan peluang baru untuk menghasilkan bahan pelbagai fungsi dan struktur untuk aplikasi yang lebih maju. Keupayaan sifat mekanikal ini akan direkodkan menggunakan pengiraan matematik dan simulasi ANSYS. Analisa di antara dua pendekatan ini akan dinilai dan dibandingkan untuk membuat korelasi yang lebih baik dan mengetahui jumlah pemuatan pengisian yang sesuai untuk meningkatkan sifat mekanikal komposit sutera. Hasilnya, melalui pendekatan pengiraan, sifat mekanikal komposit sutera dapat diramal di mana dengan penambahan jumlah pengisi karbon sifat mekanikal meningkat pada 10% dan mula menurun pada 40% dengan sokongan analisis ANSYS. Dalam pendekatan analisis, hasil yang diperoleh sedikit berbeza dari teori namun masih menunjukkan peningkatan sifat mekanikal terhadap komposit. Kesimpulannya, pendekatan teori dan simulasi terhadap penyiasatan potensi sifat mekanikal komposit sutera dengan penambahan serbuk karbon untuk pembangunan produk yang mesra alam menunjukkan sifat mekanikal yang baik.

ABSTRACT

Natural fibre is a substitute for the engineered fibre that have been widely used in various industrials and commercial applications since there are yields with high potential to improve their product. This is due to the inherent properties of natural fibres such as low cost, lightweight, renewability and environmentally friendly compared to synthetic fibres. Among natural fibres, silk is a natural animal fibre that widely used due to its limitless applications since it is strong, filiform fibre and possesses excellent mechanical properties. However, it is rare to use silk as reinforcement due to the high cost and least information on the mechanical properties. This study is about to investigate the performance of reclaimed carbon dust filler on mechanical properties of silk fabric composite. A combination of these fibre and filler will offer a new opportunity to produce multifunctional materials and structures for advanced applications. The performance of the mechanical properties recorded using mathematical and ANSYS approach analysis. The analysis between those two approaches be analyzed and compared to create a better correlation and to know the suitable amount of filler loading that can improve the mechanical properties of silk composite. As a result, it shows that in calculation approach, the mechanical strength of silk reinforced composite can be improved and enhanced by the addition of filler content from 10% to 40% where at 40% the mechanical properties start to decrease and this has been validated by ANSYS simulation. In the analysis approach, the result obtained slightly different from the theoretical but still shows an improvement towards the composite. As a conclusion, the potential mechanical properties of silk composite after being added with carbon dust filler for the development of environmentally friendly products and has shown promising performance in mechanical properties.

DEDICATION

To my beloved father, R Azmi bin Dalgiri,
my beautiful mother, Raja Karbiah binti Raja Salim,
my mischievous yet kind sister and brother, Fana and Aboi,
for giving so endlessly support and encouragement during my years in UTeM,
thank you so much and love you to the moon and back.

To my supervisor,
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To all my friends and you know who you are,
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May Allah ease our journey and bless with abundance bless, InshaAllah.

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In the name of Allah, the most gracious, the most merciful with the highest praise to complete this final year project successfully without difficulty.

From this project, I had gain a lot of experiences and new knowledges in engineering field. I am deeply indebted to my respected supervisor, Dr. Zurina bt Shamsudin for her kind supervision, advice and guide as well as meaningful experiences throughout this project. Besides, her supervision and support that gave me truly helps during the period in conducting the final year project.

Next, I would like to dedicate my thankful to panels for their assistance and help in teach me a lot of knowledge to improvise my project study.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ANSYS	-	Analysis System
Ap	-	Antheraea pernyi
ASTM	-	American Society for Testing and Materials
BCE	-	Before Common Era
Bm	-	Bombyx mori
CAD	-	Computer-Aided Design
CATIA	-	Computer Aided Three Dimensional Interactive Application
CFE	-	Crash Force Effiency
CFRP	-	Carbon Fibre Reinforced Composite
FFRP	-	Flax Fibre Reinforced Composite
GFRP	-	Glass Fibre Reinforced Composite
ISO	-	International Organization of Standardization
rCD	-	reclaimed Carbon Dust
ROM	-	Rule of Mixtures
PP	-	Polypropylene
SEM	-	Scanning Electron Microscope
SFRP	-	Silk Fibre Reinforced Composite
TETA	-	Triethylenetetramine
UTM	-	Universal Testing Machine
UTS	-	Ultimate Tensile Strength

LIST OF SYMBOLS

wt.%	-	weight percentage
mm	-	millimeter
g/cm^3	-	gram per cubic centimeter
$MPa/g\ cm^{-3}$	-	Mega Pascal per cubic centimeter
MPa	-	Mega Pascal
GPa	-	Giga Pascal
σ	-	sigma for stress
kJ/mm^2	-	kilo Joule square millimeter
°F	-	degree of Fahrenheit
°C	-	degree of Celsius
J	-	Joule
V	-	Volume fraction

CHAPTER 1
INTRODUCTION

1.1 Background study

For a few decades, natural fibres have been widely used in the industry of various sectors ranging from the packaging of food to automotive industries. They have caught quite an attention to the academic world and industry as an alternative to synthetic fibres. Natural fibres are mainly attractive because of the reasons which are specific properties, price, superior corrosion resistance and recyclability. In this study, the selected natural fibre is silk, a fine continuous protein fibre produced by domesticated silkworms and utilization in the textile industry (Merriam-Webster.com Dictionary, 2020). This single specimen is capable of producing a thick thread over 900 meters long enough to weave material. Silk belongs to one of the most precious and vulnerable parts of Chinese cultural heritage. It existed in years before the middle of the 3rd millennium BCE. They have a long history of silk culture in China been discovered that a large number of valuable silk fabrics in various ancient tombs. Recently, silk seems to be useful because of its physical properties, one of the strongest natural fibres. This natural fibre might be used as a reinforcement with other material because of its characteristics to form a composite with good mechanical and thermal properties. According to Marine *et al.* (2017), several composite materials using silk as a matrix or reinforcement have been prepared for biological applications.

Many researchers evaluated the mechanical properties of their composite by using calculation and simulation not by using machine testing in the lab. With the help of mathematical approach and ANSYS simulation, they can obtain the analysis and result of mechanical properties such as tensile strength, toughness and impact strength. Thus, this study is needed to embark on new knowledge and skills in simulation to gain an understanding of the application of silk reinforced composite on filler loading towards mechanical properties of reinforced composite that may affect the results.

1.2 Problem statement

There are some problem statement needs to be considered by investigating the material used in order to solve the problem of this study. Recently, expanding environmental towards sustainability countries has led to strict policies in concern to persuade industry to produce an eco-friendly product. As stated in the background study, natural fibres can produce many types of reinforcement in composites. Although a range of composites contains silk that has been designed, the mechanical properties achieved for the regenerated silk remain weak because of the reinforcement. Besides, the main concern of this study is to reinforce the silk with filler to improve the properties of the materials. The selected filler is carbon dust from trimming waste which is disposal that can be recycled to be used with reinforced material. Millions of tons of waste are discarded every year in incinerated, recycled or dumped landfills. The researchers found an alternative to the waste because they might be contributing to the production industry by adding value to the products. They have reinforced the natural fibres, silk with filler as it may prove that they can reduce environmental pollution through a combination of biodegradable or recycled filler materials.

Firstly, the silk fabric is rarely used because of the high cost and the least information about material properties. It needs to reinforce silk with selected filler, carbon dust. But there is a problem where need to predict the suitable amount of carbon dust that will be reinforced with silk composite and its involving formula and calculation. By using mathematical approach as the method to solve the problem, the study can determine the suitable weight fraction of filler loading in order to obtain improving mechanical properties of silk composite. According to Youssef K. *et al*. (2018), silk exhibits higher mechanical performance than plant fibres and in some cases comparable specific mechanical properties to glass fibres. By reinforcing the material, the result can achieve more useful material that can be used and help the industry. This type of reinforcement with composite will turn the overall properties such as tensile, impact or even the physical properties of composite material and reduce the cost. Without this study, it is not easy for the industry to create a sustainable product that could negatively affect the environment as it may destroy most of the lands and water to achieve its mission. For example, tensile and impact strength of the mechanical properties of composite because the collected data is only calculated using formula and equation. In order to analyze the relationship between filler loading and silk, it is required to run the analysis by using ANSYS simulation to get a rigid result. From the simulation, the sample can be design followed to our requirement and obtain the results.

Based on the prediction, thus the reinforcement and filler can work well to improve the mechanical properties and solve all of the problems mentioned in this section. Furthermore, it may be another composite material alternative that is low cost to manufacture the product.

1.3 Objective

The objectives of this study are as follows:

1) To predict the influence of carbon dust at different filler loading on the mechanical properties of silk reinforced composite using mathematical approach.
2) To analyze the correlation between the filler loading on performance computing using ANSYS simulation.

1.4 Scope of the study

The scope of the study is listed down to specific scopes that been identified based on objectives. Among the scopes listed is the material with unidirectional fibres in layers of silk fibre and carbon dust used as the primary material because in this study it used longitudinal fibre formula to calculate the mechanical properties using mathematical approach. It is because the fibres are layer in a longitudinal direction. The epoxy resin is under thermosets known as three dimensional crosslinked network. Thermosets have an advantage in incorporating fibres compared to thermoplastics. The research on the amount percentage of the materials needed to generate a composite which resulting in mechanical properties of silk reinforced composite. The samples reinforced with filler loading, carbon dust of different weight fractions (10%, 20%, 30% and 40%). The outcome of this study, to reduce the layers of silk in the composite by replacing it with carbon dust filler. It aims to develop a low-cost composite and has high mechanical properties even though not using entirely silk fibre. The results of the study can clearly state the differences in strength, tensile and also including the interphase and interface of materials by running analysis and compared the results using mathematical approach and simulation to calculate the mechanical properties involved.

CHAPTER 2
LITERATURE REVIEW

2.1 Type of Natural Fibre

According to Sen *et al.* (2016), natural fibre is inexhaustible resources with a few points of interest on them that may help the industry. These materials have outstanding mechanical properties such as it can impart the composite in high specific stiffness, tensile and strength, biodegradable, have attractive fibre aspect to ratio and consistently available from a natural source to be utilized or reap. Natural fibre may lead to advanced advantages compared to synthetic fibres due to their abundance, availability and low cost (Arpitha & Yogesha, 2017). It is because these materials can be used to reinforce both thermoplastic and thermosets matrices in order to enhance their quality and properties. Thermoplastic such as polypropylene, polyethylene and polyolefin while thermosets such as epoxy resins, polyester and polyurethane are commonly used composites because it is required in higher performance applications. These materials can provide sufficient mechanical properties in certain stiffness and strength at low price levels.

There are various types of natural fibres have been found existed nowadays. Mochane *et al*. 2019 stated that natural fibre is extracted from different renewable sources mainly from plant, animals or minerals. Mittal *et al*. 2016 stated that, there are two types of natural fibre from plants. The main is primarily fibre directly obtained from plant root while the other is secondary fibre, which is the by-product from the utilization of the primary fibre. Examples of primary fibres are hemp, kenaf, sisal and cotton while for secondary fibres are wheat straw, pineapple, *etc.* Figure 2.1 shows the classification of different natural fibres.

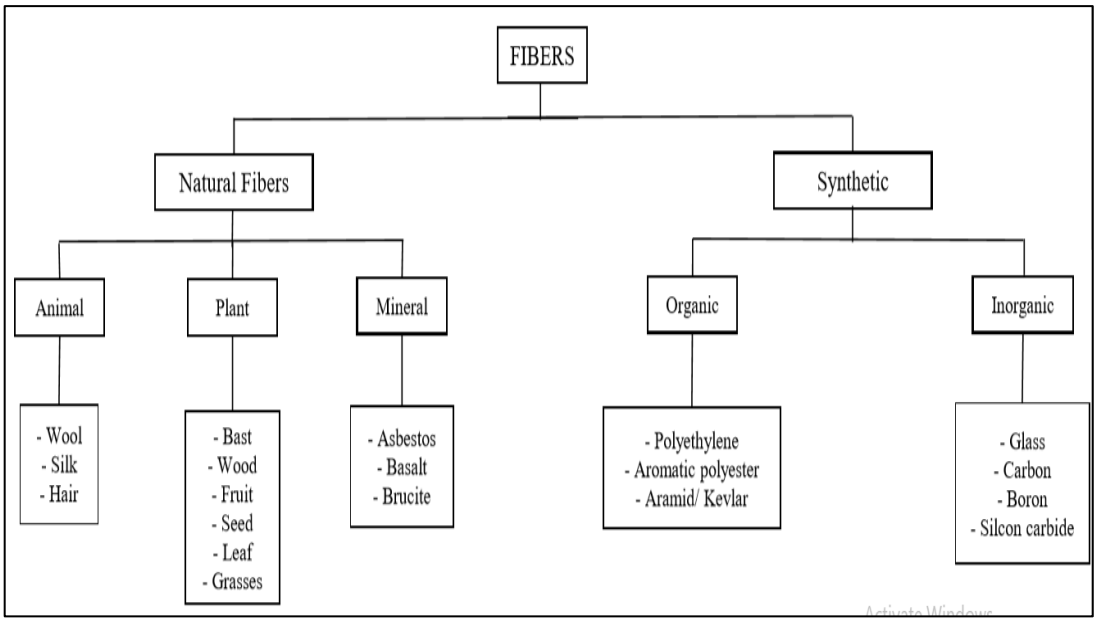

Figure 2.1 The classification of fibres (Mochane *et al*., 2019)

In addition, silk is listed under animal in natural fibres need to be used in this research to achieve the objectives of the study. The table 2.1 shows the natural fibre advantages and disadvantage listed below for further understanding.

Table 2.1 Natural fibre advantages and disadvantages (Mochane *et al*., 2019)

Advantages	**Disadvantages**
Recyclable	High moisture absorption
Light weight/ Low density	Dimensional instability
High specific mechanical properties than glass	Low strength and thermal resistance than glass fibres
Produce no harmful gasses during handling and irritating skin	Scent aging during degradation

2.1.1 Silk fibre

Silk has occupied a leading position in textile industries because of its luminescence and superb mechanical properties even though there is the least information. Silk yarn is easier to get from the waste of the fabric so the composite can be re-used as a matrix. It is also cost-effective. Silk fibres are removed from silkworms for apparel purposes since old occasions which hundreds of years back until now. Khanam *et al*. 2015 stated that there are many insects produce silk such as mulberry silk moth, *Bombyx mori*, spider, bee and other

insects. Still, the only insects that produced silk filament for commercial silk industry are from *Bombyx mori* and mulberry silk moth. Besides, according to Du *et al*. 2016 explained that apart from domestic silkworm silk, there are wild silkworm silk has been evaluated into special research because of their credit to its specific amino acid sequence that might give an advantage to processing material. For example, the pernyi silk has a lower crystallinity, hence a lower strength but superior elasticity and toughness (Zhang *et al*., 2010). Silk is utilized as reinforcement with various polymers to produces a composite that produce great mechanical and thermal properties such as high strength, flame resistance, extensibility and compressibility (Pickering *et al*., 2015; Hamidi *et al*., 2018). Silk exhibits higher mechanical performance than plant fibre. The *Bombyx mori* silkworm consists of a fibrous core protein named fibroin and a group of glue-like proteins named sericin that surround the fibroin thread together (Khanam *et al*., 2015). The compositions of fibroin and sericin proteins for each insect are different. Moreover, the commercial silk fibre *Bombyx mori* has a modulus of about 10 GPa with a strength of 400 MPa. The important strength parameter is fibre diameter, ranging from 20 μm to a few tens of nanometer (Chen, 2011).

In recent years, there are increasing interest in the application of silk fibroin for the development of biotechnological uses, such as biodegradable plastic and medical devices such as ultrasound machine (Shen, 2019). Despite the increasing interest towards which type of silk should be selected, a fundamental understanding on the adhesion between the layers of silk, fibroin and sericin need to be achieved. The understanding could offer inspiration to the design of composite materials with a tremendous interfacial bond between different components and their superior properties.

2.1.2 Physical and mechanical properties of silk fibre

Various trials have been made in developing and produce the reinforcement of the new material which can replace the current materials to produce superior physical and mechanical properties of different applications. Table 2.2 shows the mechanical properties of some natural fibres for further understanding. The properties of each natural fibres are differed due to fibre types as well as growing conditions, harvesting time, extraction treatment and capacity procedures (Pickering *et al*., 2016).