UNIVERSITI TEKNIKAL MALAYSIA MELAKA

COMPARISON OF EMPIRICAL AND EXPERIMENTAL STUDIES ON DYNAMIC MECHANICAL BEHAVIOR OF NANOCELLULOSE NATURAL FIBER IN RUBBER BASED DAMPING MATERIAL

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

by

GAN CHIN KET

B051610022

960508-08-6051

FACULTY OF MANUFACTURING ENGINEERING

2020

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

Tajuk: **COMPARISON OF EMPIRICAL AND EXPERIMENTAL STUDIES ON DYNAMIC MECHANICAL BEHAVIOR OF NANOCELLULOSE NATURAL FIBER IN RUBBER BASED DAMPING MATERIAL**

Sesi Pengajian: **2019/2020 Semester 2**

Saya GAN CHIN KET (**960508-08-6051**)

mengaku membenarkan Laporan Projek Sarjana Muda (PSM) ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. *Sila tandakan (√)

☐ SULIT (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysiasebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)

☐ TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/ badan di mana penyelidikan dijalankan)

☑ TIDAK TERHAD

Disahkan oleh:

GAN

Alamat Tetap:
No 12, Jalan TP4A,
Taman Perdana,
45300 Sungai Besar, Selangor.
Tarikh: 28th AUGUST 2020

Cop Rasmi:
PROF. DR. QUMRUL AHSAN
Profesor
Fakulti Kejuruteraan Pembuatan
Universiti Teknikal Malaysia Melaka

Tarikh: 01/09/20

*Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I hereby, declared this report entitled "Comparison of Empirical and Experimental Studies on Dynamic Mechanical Behavior of Nanocellulose Natural Fiber in Rubber Based Damping Material" is the result of my own research except as cited in references.

Signature : GAN ....

Author's Name : GAN CHIN KET

Date : 28th August 2020

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:

……………………………………

(PROF. DR. QUMRUL AHSAN)

ABSTRAK

Penyelidikan ini memfokuskan pada perbandingan kajian empirikal dan eksperimen terhadap tingkah laku mekanik dinamik serat semula jadi nanoselulosa dalam bahan redaman berasaskan getah. Getah asli disediakan oleh Sunrich Integrated Sdn Bhd dan serat jute disediakan oleh Bangladesh Jute Research Institution. Kajian ini bertujuan untuk mengetahui sifat redaman nanokomposit getah asli yang diisi oleh gentian jute. Pengekstrakan nanoselulosa serat jute dilakukan melalui rawatan alkali (8% berat NaOH) dan hidrolisis asid (3,7% berat HCl). Kumpulan fungsi kimia serat rami sebelum dan selepas rawatan kimia dicirikan dengan menggunakan Fourier Transform Infrared Spectroscopy (FTIR). 2.5 wt. %, 5 wt. % dan 10 wt. Komposit nanoselulosa serat jut / getah asli telah dibuat. Rumusan nanokomposit getah gentian jute telah dikenal pasti. Pemuatan serat rami dari komposit getah asli kemudian diletakkan di dalam pengadun dalaman dan menjalani pemvulkanan menggunakan penekan hidraulik 50 tan. Sifat redaman dari bahan gentian jute yang berbeza dari bahan redaman berasaskan getah telah dianalisis melalui Analisis Mekanikal Dinamik. Satu usaha telah dilakukan untuk menghubungkan nilai eksperimen dan teori modulus penyimpanan. Persamaan Guth dan persamaan Einstein telah digunakan untuk menilai modulus penyimpanan perbandingan komposit getah pemuatan gentian jute yang berbeza yang diperoleh dari DMA oleh kajian eksperimen. Penggunaan dan batasan persamaan teori untuk meramalkan modulus penyimpanan nanoselulosa / getah asli serat jut telah dibincangkan.

ABSTRACT

This research focuses on comparison of empirical and experimental studies on dynamic mechanical behavior of nanocellulose natural fiber in rubber based damping material. The natural rubber is provided by Sunrich Integrated Sdn Bhd and jute fiber is provided by Bangladesh Jute Research Institution. The study aims to determine the damping properties of jute fiber filled natural rubber nanocomposite. The extraction of jute fiber nanocellulose is carried out by through alkaline treatment (8 wt. % NaOH) and acid hydrolysis (3.7 wt. % HCl). The chemical functional groups of jute fiber before and after chemical treatment has been characterized by using Fourier Transform Infrared Spectroscopy (FTIR). The 2.5 wt. %, 5 wt. % and 10 wt. % jute fiber nanocellulose/natural rubber composites have been fabricated. The formulation of jute fiber rubber nanocomposites have been identified. The different jute fiber loading of natural rubber composites were then placed inside the internal mixer and undergo vulcanization using 50 ton hydraulic press. The damping properties of different jute fiber loading of rubber-based damping material have been analyzed through Dynamic Mechanical Analysis. An attempt has been made to correlate the experimental and theoretical values of storage modulus. Guth equation and Einstein's equation have been used to evaluate the comparison storage modulus of different jute fiber loading rubber composites obtained from DMA by experimental studies. The use and limitations of theoretical equations to predict the storage modulus of the jute fiber nanocellulose/natural rubber have been discussed.

DEDICATION

Dedicated to

my beloved father, Gan Kim Huat

my appreciated mother, Ng Siew Kim

my adored sister and brother, Gan Chin Soon and Gan Shirying

for giving me moral support, money, cooperation, encouragement and also understandings

Thank You So Much & Love You All Forever

ACKNOWLEDGEMENT

Firstly, I would like to thank for God for his never-ending grace, protection and mercy during the period of Final Year Project. I really appreciate from all of the God's bless I study in an excellent University environment and provides the sufficient lab infrastructure and equipment to us.

Besides, I would like to thank to my beloved and respected supervisor, Prof. Dr. Qumrul Ahsan for his advices, guidance, valuable knowledge and information. I would like to express my utmost gratitude to him which help to monitor me in completing the Final Year Project on time and fulfill all of the requirements.

I would to thanks my parents and siblings who always encourage and support me to face the difficulties and challenges. With the love and care make me work harder and brave to finish my work.

I would like to give a special thanks to technicians and friends, especially Pei Chin and Sook Ee who always assist me and discuss the problem that we have faced together. Suggestions and comments from them make me more understand about my problems.

Lastly, I would like to thank everybody who give me encouragement and moral support throughout this project and I would like to apologize to those I could not mention personally each one of you.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

NaOH	-	Sodium hydroxide
HCl	-	Hydrochloric acid
DMA	-	Dynamic mechanical analysis
CB	-	Carbon black
FTIR	-	Fourier Transform Infrared Spectroscope
SMA	-	Shape-memory alloys
SDOF	-	Single-degree-of-freedom system
VEM	-	Viscoelastic material
FRF	-	Frequency response function
TVDs	-	Tuned viscoelastic damper
TEM	-	Transmission electron microscope

LIST OF SYMBOLS

L	-	Liter
mm	-	Millimeter
%	-	Percent
g	-	Grams
wt. %	-	Weight percent
ml	-	Milliliter
MPa	-	Mega Pascal
GPa	-	Giga Pascal
°C	-	Degree Celsius
kg	-	Kilogram
δ	-	Zeta
η	-	Loss factor
nm	-	Nanometer
cm^3	-	Centimetre cube
min.	-	Minute
rpm	-	Revolution per minute
Hz	-	Hertz

CHAPTER 1

INTRODUCTION

1.1 Research Background

Generally, the word damping is used to define the process by which the amplitudes of oscillation in a mechanical system or an equipment are decreased by irreversible removal of vibratory energy. Damping is most apparent in resonance where the inertia forces and stiffness of component are same (Akay A *et al.*, 2014). Damping is usually measured under cyclic or near-cyclical conditions. Damping is energy extraction from a vibratory process. The lost energy is either transmitted or dissipated within the system or by some radiation process. Damping is responsible for the eventual decay of free vibrations and offers a reason that the response of a resonant excited vibratory system does not expand without limit (Crandall, S., 1970).

Vibration damping materials are primarily metals and polymers. Iron-based alloys, shape-memory alloys (SMA's), ferromagnetic alloys and other alloys are metals for vibration damping. However, cost for manufacturing metal matrix composites are very high and it is difficult to compete with high damping alloys (Chung, D.D.L, 2001).

Rubber, an ideal material for use in vibration damping. Rubber absorbs energy before dissipating it as heat into atmosphere, helping to isolate vibration quickly. Rubber provides high strength, excellent resistance to fatigue, high resilience, low sensitivity to stress effects in dynamic applications and good resistance to shrinkage. Because of its combination of properties, rubber is used in assemblies (Azammi, A. N. *et al.*, 2018).

Reinforcing fillers are usually applied to rubber in order to enhance the strength and endurance, abrasion resistance, toughness and modulus. Carbon black (CB) is widely use as reinforcement agent for rubber (Rattanasom, N. *et al.*, 2007). However, CB is charged with consuming the depleting oil resources for its production and contribute to greenhouse gas accumulation. Therefore, researchers prefer to explore bio-based materials as alternatives to CB in rubber (Chen, W. J. *et al.*, 2014).

Nanocellulose is an excellent, sustainable and abundantly available natural raw material characterized by exciting properties such as biodegradability, low cost and broad chemical-modifying capacity (Nunes, R, 2017). Vulcanizing temperature of rubber is between the range of 160 ˚C to 220 ˚C (Bhowmick, A. K. *et al.*, 1979). Nanocellulose with higher decomposition temperature process which is more suitable for high temperature process and more favorable when vulcanizing rubber.

1.2 Problem Statement

Almost all rubber compounds use carbon black (CB) as a filler which functions to strengthen and improve the physical properties of rubber. Carbon black is non-biodegradable. Natural filler is introduced to replace carbon black. Natural fiber is substituted to carbon black as co-reinforcing rubber while maintaining rubber/ carbon filler composite mechanical properties. With the presence of natural fiber, the rubber/ carbon filler composite will become more biodegradable.

Jute fiber is a kind of hollow natural fiber with several internal lumens, which is widely used in damping modification for composite materials. Jute fiber in nanocellulose form is a biodegradable and sustainable natural raw material which could replace carbon black as filler in rubber.

With the emergence of nanotechnology, researchers have redirected and used them in technological applications to remove nanocellulose from different plants sources. Nanocellulose with higher decomposition temperature which is more suitable for high temperature process and more favorable when vulcanizing rubber. Jute fiber reinforced composite with robust damping behavior is economical to increase energy attenuation in the application of engineering system.

1.3 Objectives

- To investigate the chemical functional groups of jute fiber before and after chemical treatment by using FTIR

- To analyze the damping properties of different fiber loading of rubber-based damping material through Dynamic Mechanical Analysis (DMA)

- To evaluate the comparison modulus of different fiber loading rubber composites obtained from DMA by experimental and empirical studies

1.4 Scope of Study

The scope of study is focused on the preparation and characterized of nanocellulose (extracted from jute fiber) through FTIR. To investigate the storage modulus and damping properties (tan delta) of different fiber loading which are 2.5 wt. %, 5 wt. % and 10 wt. % of rubber-based damping material through Dynamic Mechanical Analysis (DMA). Study of Guth and Einstein's equations to evaluate the theoretical storage modulus and make a comparison with the experimental storage modulus values. To analyze the deviation of the storage modulus results obtained from experimental and analytical.

1.5 Rational of Research

The rational of research as follows:

1. The researchers emphasized the mechanical properties of nanocellulose-based polymer nanocomposites.

2. To gain more information in favor of experimental research. Develop a better understanding on damping properties of nanocellulose-filled rubber nanocomposites.

1.6 Summary of Methodology

The entire research includes 3 main parts which are: stage 1 is the preparation of nanocellulose and characterized by FTIR. Stage 2 is dynamic mechanical analysis on different fiber loading rubber composites. Stage 3 is the comparison of storage modulus obtained from experimental with theoretical prediction of storage modulus.

1.7 Thesis Organization

Chapter 1 is begun with research background, problem statement, objectives, and scope of study, rational of research and summary of methodology. Chapters 2 literature review comprises previous study or research with any relate to the nanocellulose filled rubber nanocomposites. Chapter 3 methodology describes and explains all the raw materials, the method used, and the testing and analysis in this research. Chapter 4 is results and discussion. In Chapter 5, conclusion and recommendation about this research are examined.

CHAPTER 2

LITERATURE REVIEW

A literature review on previous research work in various areas which are relevant to this research is presented in this chapter. There will also a brief explanation on damping mechanism and damping properties of rubber and types of damping treatment. Extraction of nanocellulose from jute fiber and nanocellulose as reinforcing agent of rubber also highlighted together with the methods. Lastly, dynamic mechanical analysis on fiber-rubber composites also being highlighted.

2.1 Rubber

Rubber is a polymer with elasticity property. There are two types of rubber which are synthetic rubber and natural rubber. Natural rubber is extracted from latex sap of trees while an artificial elastomer is a synthetic tuber. Most of the synthesized polymers are petroleum by-products. The most popular synthetic rubber is Styrene Butadiene Rubber (SBR) which is used for producing tires.

2.1.1 Vulcanization of Rubber

Based on Encyclopedia Britannica, vulcanization is a chemical process of improving the physical properties of natural or artificial rubber. Finished rubber has a higher tensile strength and swelling abrasion resistance and is elastic over a wider temperature range. Temperatures of around 140 ˚C to 180 ˚C is applied for vulcanization.

According to Mukhopadhyay, R. *et al.*, 1979 studied, there are four majority changes caused by vulcanization. Firstly, rubber is essentially changed from plastic to non-plastic. Secondly, in a variety of solvents, rubber is modified from a substance soluble to one that is insoluble. Thirdly, rubber is converted into a substance with significantly improved physical properties. Lastly, these vulcanized rubber properties are maintained at a much wider temperature range than un-vulcanized rubber.

2.2 Natural Fiber

Based on Saheb, D. Nabi *et al.*, 1999 studied, a lot of conventional metals/materials were replaced by polymers in various application. Ease of production and low cost are the main advantages of using polymers. The properties of polymers are improved to meet the high strength and high modulus requirements by using fibers as fillers. Fiber-reinforced polymers, when compared to specific properties, offer advantages over other conventional materials.

According to Joshi, S. *et al.*, 2004 studied, natural fiber composites are also claimed to offer environmental advantages such as reduced rely on non-renewable energy or material sources, lower the carbon footprints, increased energy recovery and biodegradable until at the end of life.

2.2.1 Jute Fiber

Jute fiber an example of natural fiber. According to Khan, R. A. *et al.*, 2009 studied, high durability, low abrasion multifunctionality, low cost, increased energy recovery and biodegradable are the advantageous of properties for jute fiber. Figure 2.1 shows the SEM images of jute fiber.

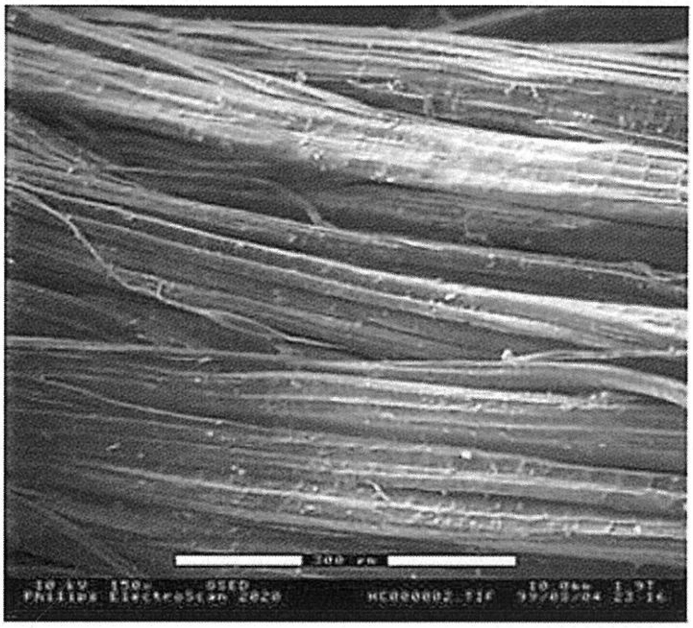

Figure 2.1: SEM image of Jute Fiber (Khan, R. A., 2009)

Glass fiber-E and jute fiber normally used as reinforcement materials. Table 2.1 shows the mechanical properties of jute fiber and glass fiber-E. Based on the table 2.1, the tensile strength of glass fibers is significantly higher than that of jute fibers. Furthermore, when considering the specific jute fiber modulus (modulus/absolute gravity), the jute fiber display values equal to or better than those of glass fiber-E. higher specific properties are one of the major benefits of using jute fiber composites for applications where weight reduction is also included in the desired properties.

Table 2.1: Mechanical Properties of Jute Fiber and Glass Fiber-E (Reproduced from Saheb, D. Nabi *et al.*, 1999)

Fiber	Specific Gravity	Tensile Strength (MPa)	Modulus (GPa)	Specific Modulus
Jute	1.3	393	55	38
Glass Fiber-E	2.5	3400	72	28