Faculty of Manufacturing Engineering

SOUND ABSORPTION CHARACTERISTICS OF SPENT TEA LEAF FIBER-RUBBER COMPOSITE MATERIALS

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SOUND ABSORPTION CHARACTERISTICS OF SPENT TEA LEAF FIBER-RUBBER COMPOSITE MATERIALS

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in the fulfilment of the requirements for the degree of Master of Science
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DECLARATION

I declare that this thesis entitled "Sound Absorption Characteristics of Spent Tea Leaf Fiber-Rubber Composite Materials" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : ....

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Manufacturing Engineering.

Signature : ....

Supervisor Name : ....

Date : ....

DEDICATION

To my beloved father, Christopher Wong

my appreciated mother, Yong Fui Yun

my adored siblings, Charlene Wong and Janice Wong

and Patrick.

ABSTRACT

Sound control has been regarded as one of the important requirements for human comfort. Conventionally, synthetic fibers, such as glass fibers are used as sound absorbing material. It was found that glass fibers present negative impacts in terms of environment ecology and human safety. Glass fibers are non-biodegradable, high in cost and unsafe during handling. Due to these aforementioned disadvantages, natural fibers have recently been gaining attention to substitute synthetic fibers as they offer some advantages including biodegradable, lower greenhouse gas emission, lower density, lower cost and user friendly. This study is intended to demonstrate the feasibility of spent tea leaf fiber (STLF), a type of natural fiber as porous sound absorbing material. STLF is a by-product obtained during the processing of tea leaves at tea plantation industry. Three different grades of STLF are studied and the acoustic property is analyzed in terms of sound absorption coefficient (SAC) and transmission loss. In this study, natural rubber (NR) latex is introduced as binder to hold the fibers in shape, producing an open-pore structure. Impedance tube measurement is performed to analyze the acoustic properties of STLF based sound absorber presented in Phase 1. Phase 2 focused on the effect of fiber grade, binder content and air gap distance on acoustic performance of STLF by using statistical factorial design of experiment. Results show that all the samples obtained maximum SAC above 0.70 at frequency range of 1990-3800 Hz. In addition, it is found that finest STLF with the average diameter of 0.129 mm exhibits better acoustic performance as compared to other two grades STLF. Phase 2 results suggest that fiber grade, binder content and air gap distance have significant effect on the acoustic performance of STLF. It is confirmed through the analysis of variance (ANOVA) test with a confidence interval of 95% in which all three selected factors show P-value < 0.0500. Generally, the sample with smallest diameter fiber grade (0.129 mm) mixed with high binder content (41 wt%), incorporated with air gap distance (30 mm) is able to absorb 98.2% of sound at frequency around 1000 Hz. Lastly, PVC perforated membrane is used as cover screen to protect the STLF. The presence of perforated membrane enhances the acoustic absorption of STLF mixed NR latex by 25.1%. The overall results indicate that STLF can be promising environmental-friendly sound absorbing material.

ABSTRAK

Kawalan bunyi merupakan salah satu keperluan penting demi keselesaan manusia. Secara konvensional, gentian sintetik seperti gentian kaca digunakan sebagai bahan penyerapan bunyi. Walau bagaimanapun, didapati bahawa gentian kaca menunjukkan kesan negatif kepada ekologi alam sekitar dan keselamatan manusia. Gentian kaca tidak terbiodegradasi, melibatkan kos tinggi dan tidak selamat semasa pengendalian. Oleh sebab itu, perhatian telah dialihkan kepada penggunaan gentian semula jadi sebagai alternatif gentian sintetik kerana gentian semula jadi menawarkan kelebihan termasuk terbiodegradasi, pelepasan gas rumah hijau lebih rendah, ketumpatan yang rendah, kos terlibat lebih rendah dan ramah pengguna. Kajian ini bertujuan untuk menunjukkan kemungkinan gentian daun teh (GDT), sejenis gentian semula jadi sebagai bahan penyerapan bunyi berliang. GDT merupakan produk sampingan yang diperolehi semasa pemprosesan daun teh di industri perladangan teh. Terdapat tiga jenis gred GDT dikaji dan sifat akustiknya dianalisis melalui nisbah penyerapan bunyi dan kehilangan penghantaran. Kajian ini memperkenalkan susu getah sebagai pengikat untuk menghubungkan gentian-gentian untuk menghasilkan struktur liang terbuka. Sifat akustik GDT dianalisis dengan menggunakan kaedah tiub impedan akustik dan ditunjuk dalam Fasa 1. Fasa 2 daripada kajian ini menekankan kesan jenis gred gentian, jumlah pengikat yang digunakan dan jarak jurang udara kepada prestasi akustik GDT dengan mengaplikasikan eksperimen rekabentuk faktorial statistik. Kajian mendapati bahawa semua sampel diperbuat daripada GDT menunjukkan nisbah penyerapan bunyi maksimum lebih 0.7 dalam julat frekuensi 1990-3800 Hz. Di samping itu, didapati bahawa GDT terhalus (dengan diameter purata 0.129 mm) menunjukkan prestasi akustik lebih baik berbanding degan dua jenis gred GDT yang lain. Hasil kajian daripada Fasa 2 mencadangkan bahawa faktor jenis gred gentian, jumlah pengikat dan jarak jurang udara memberikan kesan penting ke atas sifat akustik GDT. Hasil ini disahkan di mana ketiga-tiga faktor ini menunjukkan P-nilai < 0.0500 dalam analisis ujian varians (ANOVA) dengan tahap keyakinan 95%. Secara umumnya, gentian terhalus (dengan diameter 0.129 mm) campur degan kandungan susu getah yang tinggi (41 wt%) serta digabungkan dengan jurang udara (30 mm) dapat menyerap 98.2% bunyi dalam julat frekuensi 1000 Hz. Selain itu, lapisan berlubang PVC digunakan sebagai skrin perlindungan sampel GDT. Kajian melaporkan bahawa penggunaan lapisan berlubang meningkatkan prestasi penyerapan bunyi GDT campuran susu getah degan 25.1%. Keputusan keseluruhan menunjukkan bahawa GDT boleh dijadikan bahan penyerapan bunyi yang menjanjikan dan mesra alam.

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LIST OF ABBREVIATIONS

ANOVA	-	Analysis of variance
DoE	-	Design of Experiment
FTIR	-	Fourier Transform Infrared Spectroscopy
NR	-	Natural rubber
NRC	-	Noise reduction coefficient
OFAT	-	One factor at a time
PET	-	Polyethylene terephthalate
PLLA	-	Poly(L-lactic acid)
PP	-	Perforated Plate
PVC	-	Polyvinyl chloride
SAC	-	Sound Absorption Coefficient
SEM	-	Scanning electron microscope
STLF	-	Spent Tea Leaf Fiber
TL	-	Transmission loss

LIST OF PUBLICATIONS

<u>Journal</u>

1. Wong, K., Ahsan, Q., Putra, A., Subramonian, S. and Nor, M.J.M., 2017. Preliminary Study on the Sound Absorption Behaviour of Spent Tea Leaves Filled with Natural Rubber Latex Binder. *Jurnal Teknologi*, 79 (5-2), pp.59-64.

2. Wong, K., Ahsan, Q., Putra, A., Subramonian, S., Mohamad, N. and Nor, M.J.M., 2017. Acoustic Benefits of Ecofriendly Spent Tea Leaves Filled Porous Material. *Journal of Key Engineering Materials*, 739, pp. 125-134.

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter introduces the background of present study, subject matter and states the problems that are being studied. Apart from that, this chapter also highlights limitations or scope covered in present study and indicates the importance of the study.

1.2 Background of Study

"Acoustics" which is derived from the Greek word (akouein) is defined as "to hear". It is the interdisciplinary of science that study sound, including its generation, transmission, analysis and perception (Mommertz, 2009). Hearing and understanding are fundamental prerequisites for communication. In fact, a good acoustic environment is important to prevent masking of speech or music by noise.

In recent years, increased population growth and advances in new technologies are often accompanied by noise pollution, apart from air and water pollution. Noise, can be referred as any undesired sound or irritating, chaotic sound which is disturbing, and can even pose health concern (Prabhakaran et al., 2014). Intensive noise can interfere with sleep, inducing psychological state of stress. Worse, long exposure to noise can lead to hearing impairment (Mahzan et al., 2009a). In addition, with the rapid development of technologies, demands for higher standards of living and diversification of life styles are increasing. As a result, sound comfort constitutes have become one of the essentials for human comfort.

In general, noise control elements can be categorized into three types. Primary method involves treatment at noise source. It is commonly named as active noise control in which large amount of external energy is applied to suppress or cancel the noise or vibration emitting element. Secondary method, commonly called as passive noise control method, involves treatment of the sound transmission path. This method comprises the installation and implementation of sound barriers or sound reduction materials to make alterations on the propagation route of sound, dissipating the noise acoustic energy into heat energy; while the third method deals with each sound receiving person, for an instance, wearing hearing protection (Yilmaz et al., 2011). In particular, primary method is restricted when cost is considered; while third method needs to deal with every sound receiver. Thus, this situation renders advantageous factor in adopting secondary method as noise control application due to the fact that it is most economical. In this respect, the secondary method focused in controlling air-borne noise by the use of sound absorbing material. Porous sound absorbing materials have been widely applied in industry, building construction, aeronautics to reduce noise by absorbing the sound energy. Present study primarily focused in porous sound absorbing material.

Nowadays, public awareness on environmental friendly and recycled products has been raised in pace with technology development. Public concerns about global environmental issues such as global warming, landfilled waste problems promote the reuse, recycling and extracting value from waste. In other words, there are increasing demands in employing environmental friendly or biodegradable materials and processes. The use of waste and recycled materials is able to minimize the demand of non-renewable resources at the mean time reduce the amount of landfilled waste (Arenas et al., 2015).

Conventionally speaking, synthetic fibers such as glass fiber, rock wool and polyester fiber are the most common materials for previously mentioned sound absorbing material. Nevertheless, it was discovered that these synthetic fiber or petroleum-based fibers present many drawbacks related to environmental, human health and safety (Joshi et al., 2004). As a result, a number of studies have been focused in employing natural fibers; or more precisely plant based fibers as an alternative for synthetic fibers to be processed as sound absorbing material. Comparatively, natural fibers present both environmental and economical benefits where they are safer to use, possess low environmental impact, biodegradable; cost involved is lower, making it a key factor for a sustainable development in building industry.

The present study is an attempt to investigate the capability of spent tea leaf fiber as an inexpensive sound absorbing material to substitute synthetic fiber for reducing the noise. Spent tea leaf fibers, a natural lignocellulosic fiber with unique aroma, were extracted from the stalks of tea plant (tea leaf). It is a by-product from tea plant industry.

The first part of the study covers the statement of problems and outlines the objectives to be achieved for this research. This is followed by chapters covering the comprehensive review of the literature related to the topic. Third chapter of this thesis is devoted to describe experimental methods in achieving the research objectives. Next, results obtained in the study were interpreted and analyzed in relation to the objectives. Last but not least, brief summary and conclusions were drawn. Suggestions and recommendations for future studies were described.

1.3 Statement of Problem

Noise is regarded as undesired, irritation sound which is disturbing and can even be unhealthy. For an instance, when an interior space where speech intelligibility is important for speech or music, distracting noises can cause poor speech or music deliverance; audience may find difficulty in understanding the presentations. On the other hand, prolonged exposure to noises in the passenger cabin of automobile can cause fatigue to the driver, which is dangerous and may affect the safety of the automobile users (Yilmaz et al., 2011). In addition, intensive noises can cause physical and mental stresses such as insomnia, decreased working performance and even worse, temporary hearing loss and hypertension for workers at the machinery industry.

Noise control elements especially porous sound absorbing materials have been widely adopted in controlling and reducing noises to provide good auditive environment. Traditionally, noise absorbing materials are synthesized by performing non-biodegradable material, generally named as synthetic or man-made fiber. Common fibers used are polymer fibers, glass wool fibers and carbon fibers. These materials are known to have exceptional mechanical performance in which they are strong and stiff. Nevertheless, over the years, it was discovered that these synthetic fibers posed negative impacts on environment and human safety (Çelebi and Küçük, 2012). Normally, synthetic fibers are produced by high-temperature extrusion and industrial process based on materials obtained from non-renewable petroleum and ores, through spinnerets forming thread form fibers. The fabrication of these artificial fibers involves high air emissions such as carbon dioxide, nitrous oxide and methane, which are hazardous to environment. Studies have reported that the production of glass mineral fiber uses 5-10 times more non-sustainable energy as compare to natural fiber production (Joshi et al., 2004). In addition, the application of synthetic fibers can cause landfilled waste problem as they are non-biodegradable. Not only that, it was found that synthetic fibers are not skin friendly and may cause discomfort during processing and handling. It was reported that synthetic fibers can cause skin irritation and pose danger to human health if the fibers are being inhaled as the fiber can stay in human lung alveoli (Alessandro and Pispola, 2005). In term of cost, the production and selling price for synthetic fibers involved are relatively higher cost compared to natural fiber, where natural fiber can be obtained from natural and abundant resources. For the above reasons, environment friendly industrial practice is now encouraged, thus 'green' and sustainable materials for sound absorbers are getting more interest.

To date, many studies have been diverted to the utilization of natural fibers as sound absorbing material because it is believed that these natural fibers offer environmental benefits. Natural fibers that have been tested for their acoustic properties include jute, coconut coir, hemp and sisal fibers. Little work has focused on acoustic properties of by-product fiber from tea plant industries. In year 2009, Ersoy and Kucuk have presented a study on tea leaf fiber. However, its functionality become limited when applied to real-world practices because these fibers are short, friable and do not hold in one shape. Hence, it is crucial to review critically the improvement of sound absorbing characteristic of spent tea leaf fiber in present study, so it can be used as an added value sound absorbing material.

1.4 Objectives of Research

The main objective of this research is to study the viability of spent tea leaf fiber, a by-product from tea plantation industry, mixed with binder as sound absorbing material. The primary objectives of this research are to:

i. Characterize physical properties of spent tea leaf fiber (STLF) in highlighting the acoustical characteristics of natural fiber.

ii. Analyze the acoustic properties of spent tea leaf fiber mixed with natural rubber latex binder.

iii. Validate parameters influencing sound absorption properties of spent tea leaf fiber mixed natural rubber latex composite via Design of Experiment (DoE).