UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DEVELOPMENT AND TESTING OF AIRFLOW RESISTIVITY SYSTEM FOR AN ACOUSTIC MATERIAL WITH RAPID PROTOTYPING

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Faculty of Mechanical and Manufacturing Engineering Technology

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A thesis submitted
in fulfillment of the requirements for the degree of
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DECLARATION

I declare that this thesis entitled “Development And Testing of Airflow Resistivity System For An Acoustic Material With Rapid Prototyping” is the result of my research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature : 

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Date : 20/01/2023

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APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (BMMV) with Honours.

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DEDICATION

I would like to give full appreciation to my father and my late mother, Ibrahim bin Awang and Siti Fatimah Binti Muda for giving moral support to me to persuade my degree especially my late mother. To my main supervisor and co-supervisor, for their guidance and encouragement, Dr. Najiyah Safwa Binti Khashi'ie and Ts Muhammad Nur Bin Othman.To all my friends for their unconditional support of me. I hereby give all my respect and appreciation to all of them because, without them, I wouldn't achieve it now.

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ABSTRACT

Nowadays, natural fiber can replace synthetic fiber as the new material for composites application in the various industrial sector because it is a more eco-friendly material compared to synthetic fiber. Natural fibers have more advantages than synthetic fibers because they are renewable, biodegradable, and carbon-neutral materials that may be used without diminishing or harming the environment. This research aims to improve the design of the airflow test rig compared to the previous design and to study the airflow resistivity of natural fiber that is rice husk based on the acoustic property of different thicknesses and densities of the natural fiber using the airflow test rig. The exact parameter of the cylinder is important to design it in SolidWorks software to make sure the specimen fits in the air flow test rig. 3D printing equipment is used to make the actual cylinder shape of the airflow test rig. The resistivity of airflow is an important requirement when using natural fiber as a material to make a product that has air flow such as bicycles, parachutes, and others. The airflow test rig is a device to measure the rate of airflow. Firstly, the mechanism of the airflow test rig is the vacuum will be attached to the airflow test rig to make a suction of airflow. Arduino Mega 2650 was used to collect the reading of differential pressure in the test rig while anemometer was used to collect the ouput velocity of airflow in the test rig. Lastly, the calculation have been made from the results of output velocity and differential pressure to obtain the air resistivity data from airflow test rig and data analysis have been made. The results of this research have been conclude that the air resistivity will decreases if the thickness increases and if density increases the airlow resistivity will decreases. All the objective was achieved. Last but not least, the research must be continued for further study because it use new material.

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ABSTRAK

Pada masa kini, serat semula jadi boleh menggantikan serat sintetik sebagai bahan baharu untuk kegunaan komposit dalam pelbagai sektor industri kerana ia lebih mesra alam berbanding serat sintetik. Serat semula jadi menpunyai lebih banyak kelebihan berbanding serat sintetik kerana ia merupakan bahan yang boleh diperbaharui, terbiodegradasi dan neutral karbon yang boleh digunakan tanpa mengurangkan atau merosakkan alam sekitar. Tujuan penyelidikan ini dijalankan adalah untuk untuk menambah baik reka bentuk rig pengujian aliran udara berbanding reka bentuk sebelumnya dan mengkaji kerintangan aliran udara serat semula jadi iaitu sekam padi berdasarkan sifat akustik untuk ketebalan dan ketumpatan serat semula jadi yang berbeza menggunakan rig pengujian aliran udara. Ukuran tepat silinder adalah penting untuk dimasukkan dalam perisian SolidWorks untuk memastikan spesimen tersebut muat dalam rig pengujian aliran udara. Peralatan percetakan 3D digunakan untuk membuat bentuk silinder sebenar rig pengujian aliran udara. Rintangan aliran udara adalah keperluan penting apabila menggunakan serat semula jadi sebagai bahan untuk membuat produk yang mempunyai aliran udara seperti basikal, payung terjun dan lain-lain. Rig pengujian aliran udara ialah peranti untuk mengukur kadar aliran udara. Pertama, mekanisme rig pengujian aliran udara ialah vakum akan dipasang pada rig pengujian aliran udara untuk membuat sedutan aliran udara. Arduino Mega 2650 digunakan untuk mengambil bacaan tekanan pembezaan dalam pelantar ujian manakala anemometer digunakan untuk mengambil bacaan halaju keluaran aliran udara dalam pelantar ujian. Akhir sekali, pengiraan telah dibuat daripada keputusan halaju keluaran dan tekanan pembezaan untuk mendapatkan data kerintangan udara daripada pelantar ujian aliran udara dan analisis data telah dibuat. Hasil kajian ini telah disimpulkan bahawa kerintangan udara akan berkurangan jika ketebalan meningkat dan jika ketumpatan meningkat kerintangan rendah udara akan berkurangan. Semua objektif tercapai. Akhir sekali, penyelidikan mesti diteruskan untuk kajian lanjut kerana ia menggunakan bahan baharu.

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LIST OF SYMBOLS AND ABBREVIATIONS

σ	-	Airflow resistivity
ΔP	-	Pressure different across a sample
A	-	Cross-sectional area of material perpendicular to the flow
BOM	-	Bill of material
CAD	-	Computer-aided design
CAM	-	Computer-aided manufacturing
D,d	-	Diameter
HVAC	-	Heating, ventilation, and air conditioning
h	-	Thickness of material
LCD	-	Liquid crystal display
LED	-	Light-emitting diode
NFRCs	-	Natural fiber-reinforced composites materials
PA	-	polyamide
Q	-	Volumetric flow rate through material
R_f	-	Flow resistance
R_s	-	Specific flow resistance
SLS	-	Selective laser sintering
USB	-	Universal serial bus
v	-	Output velocity

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CHAPTER 1

INTRODUCTION

1.1 Background

Natural fiber is a raw material or porous material that is gained from natural resources such as vegetable fiber, animal fiber and mineral fiber. The most common natural fiber is cotton, bamboo and flax which are produced from the plant. Besides that, the natural fiber is from an animal such as silk, wool, mohair and angora (Barnhardt, 2019). Nowadays, many industries have started to use natural fiber as a material for their building materials, particle boards, pharmaceuticals, biopolymers, and fine chemicals (Keya et al., 2019). Natural fiber can be decomposed naturally by microorganisms such as fungi and bacteria compared to synthetic fibers which are hard to get rid of.

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Natural fibers have been used for textile materials since before recorded history. The oldest evidence of fiber use is possibly the discovery of flax and wool fabrics at Swiss lake dwelling excavation sites (7th and 6th centuries BCE). Prehistoric peoples also employed a variety of vegetable fibers (Britannica, 2020).

According to Textile School (2018) the first composite material in history was probably constructed with clay and straw to build walls in Egypt 3000 years ago. Hemp, along with linen, was first cultivated in China about 2800 BC and is one of the oldest natural fibers used to make products. Hemp was cannabis in Greek and Latin nomenclature, which led to the name canvas since hemp was used to make sails for boats. Similarly, in the past, nettle was used to make fishing nets.

The resistivity of airflow is an important requirement when using natural fiber as a material to make a product that has air flow such as bicycles, parachutes, and others. The airflow resistivity is related to the acoustic properties of the fibrous material (Tang & Yan, 2020). A study can be done to make an analysis of how the airflow resistivity reacts to different thicknesses and densities of the natural fiber using an airflow test rig. The research was conducted using an airflow test rig to measure the rate of airflow.

1.2 Problem Statement

There is a certain thing that must be considered to avoid failure when doing the experiment. This research is about finding the best natural fiber characteristic to make new technology that is environmentally friendly compared to synthetic fiber. So, the different natural fiber is prepared from the existing study and different design of the test rig is used using 3-dimensional (3D) printing equipment. The design of the test rig will be analyzed using experimental design method that will be discussed in the methodology to make sure the experiment gets the best design. It is important to get the best design to make sure the objective of this project is successful. After determining the best design, the cylinder of the airflow test rig is created using SolidWorks software and then 3D printed. Therefore, the exact parameters of the cylinder must be considered when designing it in SolidWorks to ensure that the specimen fits securely in the airflow test rig..

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Natural fiber has various advantages, but they also have certain weakness, such as natural fibers have lower strength than synthetic fibers, are heavy, have wrinkled fibers, can be damaged by moths and other insects, and these fibers are not very long-lasting, thus they are not very durable (Philoid, 2022). There are some natural fibers not suitable to use in the laboratory when using airflow test rig equipment. In order to reduce the risk of failure, it is crucial that the process of

preparing natural fibres, including determining their thickness and density, be executed appropriately.

1.3 Research Objective

There are three objectives for this research that can be done using airflow test rig and natural fiber specimen. The objective of this research as follows:

a) To design the cylinder of the airflow test rig using SolidWorks software.

b) To improve the existing airflow test rig model and measure airflow resistivity using Arduino Mega configuration.

c) To analyze the airflow resistivity of rice husk with different thicknesses, mass and density of the natural fiber by using an airflow test rig.

1.4 Scope of Research

The scope of this research consists of designing, fabricating, testing the airflow test rig and analyze the results of airflow resistivity of specimen:

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a) To design a cylinder of rig tube by using using experimental design method such as Morphology chart, Conceptual design and Pugh method to produce the best design using SolidWork software.

b) A new enhancement was made for the rig tube compare to the previous design using 3-dimensional (3D) printing equipment and Arduino Mega 2560 was used to record the differential pressure data.

c) Rice husk was choosen as natural fiber specimen with different thickness (40 mm, 50 mm and 60 mm) and density (100 g/cm^3, 120 g/cm^3 and 140 g/cm^3). The output velocity and differential pressure was recorded for the data analysis.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter provides an overview of existing knowledge on a certain topic of research. It also provides a background of the study by summarizing previously published work that is almost identical to this project. The existing research that has been discussed in the literature review was gained from many sources like journals, and books that can be compared to this research. ScienceDirect, Scopus, and Google Scholar were used to search journals that related to this research.

2.2 Definition of Fiber

Fibers have long been utilized in all cultures around the world to provide fundamental needs for clothing, storage, construction materials, and daily use like ropes and fishing nets. Fiber basically is hair-like strands that make up a fabric vegetable tissue or muscle. Fibers also can be defined as long strands of molecules intertwined to produce a linear, string-like structure (Toppr, 2020). Fiber consists of two types which are natural fiber and synthetic fiber. Natural fibers come from plants, animals, and minerals, whereas synthetic fibers are totally man-made and are created from petrochemicals such as nylon, rayon, and polyester. Synthetic fibers can be summarized as artificially manufactured fibers in chemical laboratories that are made up of several repeating units known as polymers. Example of natural fiber is cotton and jute that is derived from plants, whereas silkworms, and wool is derived from sheep's hair (Ankita Sahay et al., 2022).

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2.3 Natural Fiber

The natural fiber is any hairlike raw material obtained directly from an animal, vegetable, or mineral source and convertible into nonwoven fabrics such as felt or paper, or into woven cloth after spinning into yarns. Natural fiber can also be characterized as an agglomeration of cells having a small diameter in relation to their length. Despite the abundance of fibrous materials in nature, particularly cellulosic forms such as cotton, wool, grains, and straw, only a small percentage may be used in textiles or other industrial applications. Besides economic factors, a fiber's commercial use is decided by features like length, strength, pliability, elasticity, abrasion resistance, absorbency and other surface properties. Most textile fibers are thin, flexible, and durable. When put under strain, they stretch and then partially or totally return to their original length when the tension is removed (Britannica, 2020). Figures 2.1 show types of natural fiber.

Figure 2.1: Natural Fiber Made from Plants (Mohamad Midani, 2022)

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2.4 Types of Natural Fiber

There are three types of natural fiber which is plant fiber or cellulose-based, animal fiber and mineral fiber. The most common plant fiber is flax, cotton and jute. The animal or protein base fibers include silk, mohair, and wool. The most important fiber in the mineral class is asbestos (Britannica, 2020). Figure 2.2 show the classification of natural fiber.

Natural Fibre	Cellulose/Lignocellulose	Bast	Flax, Hemp, Jute, Kenaf, Ramie
		Leaf	Abaca, Banana, Pineapple, Sisal
		Seed	Cotton, Kapok
		Fruit	Coir
		Wood	Hardwood, Softwood (e.g., Eucalyptus)
		Stalk	Wheat, Maize, Oat, Rice
		Grass/Reed	Bamboo, Corn
	Animal	Wool/Hair	Cashmere, Goat hair, Horse hair, Lamb wool
		Silk	Mulberry
	Mineral	-	Asbestos, Ceramic fibres, Metal fibres

Figure 2.2: Natural Fiber Classification (Peças et al., 2018)

2.4.1 Plant Fiber

Plant fibers are widely used in industrial applications today such as in the automotive industry and many more. It offers more durability and lower density, cost and energy consumption compared to synthetic fiber in industrial applications (Karimah et al., 2021). Plant fibers can be classified into smaller groups based on their origin. Cotton, kapok, and coir are examples of fibers that began as hairs on the seeds or inner walls of the fruit, each of which is made up of a single, long, narrow cell. All vegetable fibers are mostly made up of cellulose, but they also contain different levels of hemicellulose, lignin, pectins, and waxes, which must be removed or reduced during processing(Britannica, 2020).

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2.4.1.1 Cotton

Cotton is organic fibers that gain from the seeds of the cotton plant. Cotton fabric on the other hand is made from the fibers that wrap the mature seeds of cotton plants, which emerge in a spherical, fluffy structure(Sewport Support Team, 2022). Cotton fiber is widely used in the textile sector, and efforts are being made to create composites from cotton material for industrial applications (Cottonworks, 2022). Cotton, like many other natural fibers, is very comfortable for human skin, soft and breathable. It is a fine, durable, and long-lasting fiber with good absorptivity (AanyaLinen, 2020).

2.4.1.2 Coir

Coir fiber gains from the fruit of the coconut tree. The part of a fruit that is on the outside is called the husk (Chand & Fahim, 2021). Coir fiber is produced from the husk of coconut fiber, which has a longer life than other fibers because of its lignin properties. Coir fiber-reinforced composites are produced for social, economic, and industrial applications, like packaging material, helmets, rope, and many other things. There are some disadvantages, like a high amount of moisture that can be fixed with chemical treatment (Keya et al., 2019).

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2.4.2 Animal Fiber

Animal fibers are obtained from proteins such as keratin, collagen, and fibroin. Wool, silk, and alpaca form a major section of animal fiber. Secretions are produced from the silkworm's larva, or worm stage, which spins the cocoon from which silk fibers are extracted, and from the spider, which spins fine fibers to make its web (Geeks, 2021). Most animal fibers fall into one of two groups based on where they come from. First, animal hair which is wool is taken from mammals that have hair such as sheep's wool and goat hair (cashmere, mohair). Secondly, silk is a fine strand of fiber made from a solidified protein secretion that produces by certain caterpillars to wrap up themselves in form of a cocoon(Brain Kart, 2018). Figure 2.3 illustrate the animal fiber and its application.

Figure 2.3: Animal Fiber Application (Toppr, 2020)

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