UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DEVELOPMENT OF AIRFLOW RESISTIVITY SYSTEM WITH RAPID PROTOTYPING AND ARDUINO CONFIGURATION

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in fulfillment of the requirements for the degree of
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DECLARATION

I declare that this Choose an item. entitled " Development of Airflow Resistivity System with Rapid Prototyping and Arduino Configuration" is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : *Afiqah*

Name : Nur Afiqah Aina Binti Zaiham

Date : 20.01.2023

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 with Honours.

Signature : *Najiyah*

Supervisor Name : Dr. Najiyah Safwa Binti Khashi'ie

Date : 20.01.2023

DEDICATION

This initiative is dedicated to my wonderful parents, Zaiham bin Awang @ Zainon and Roziah Binti Daud, as well as all of my siblings. I'd like to thank my supervisor, Dr. Najiyah Safwa Binti Khashi'ie, as well as all of my instructors at Universiti Teknikal Melaka Malaysia (UTeM), for her advice and assistance with this project. Finally, thank Allah SWT for the successful completion of this project and its proper operation as planned.

ABSTRACT

The purpose of this study is to broaden the scope of research on natural fiber acoustic since there have been least studies on air flow through natural fiber. Besides that, to provide the further research with exposure to these types of devices and to get the data faster and more accurately compared to the previous research. An existing low-cost airflow test rig was design with improvement in certain part with the ability to analyse a variety of samples using an Arduino configuration. This can contribute to enhance awareness of the various types of natural fibres and, in turn, limit the use of synthetic fiber in industry. The objective of this study is to design an improvement on existing airflow test rig. Next, to developed the improved test rig using 3D printing machine. Lastly, to analyse the airflow resistivity on different thickness of the durian inner peel fiber using airflow test rig with the aid of Arduino configuration. To accomplish the first objective of this project, which is to design an improvement on existing airflow test rig, the morphology chart, conceptual design, and Pugh method were employed. The concept design 3 with highest total score in Pugh method was chosen as the best concept design compared to the other designs. Besides that, in order to achieve the second objective which is a development of improved test rig using 3D printing machine, it can be done by using Farsoon 402P Selective Laser Sintering (SLS) 3D printing machine available in university. Furthermore, to achieve the third objective of this project which is to analyse the airflow resistivity on different thickness of the durian inner peel fiber, it needs to be analysed through the testing when the air passes through the specimen using an airflow test rig. In order to get the value of differential pressure and output velocity accurately through this testing, it can be obtained with the aid of Arduino configuration and anemometer. The results show the output velocity become lower, meanwhile the differential pressure become higher as the thickness of the specimen increases. However, the airflow resistivity can be obtained from the manual calculation. Based on the results, the specimen with higher thickness will result in lower airflow resistivity. These airflow resistivity data, whether at low or high speed, are significant after being analysed using linear regression method. The linear regression analysis of variance table with P-value less than 0.05 is shown in this statistical method analysis at both speeds. Due to the microstructure and the arrangement of the durian inner peel fiber is greater, it has been chosen as a natural fiber acoustic to be used for this research. In this case, lower airflow resistivity considered as the best sound absorption coefficient as the least amount of sound velocity can penetrates the fiber.

ABSTRAK

Tujuan kajian ini adalah untuk meluaskan skop penyelidikan tentang akustik gentian semula jadi memandangkan terdapat kurang kajian mengenai aliran udara melalui gentian semula jadi. Selain itu, untuk menyediakan penyelidikan lanjutan dengan pendedahan kepada jenis peranti ini dan untuk mendapatkan data dengan lebih cepat dan lebih tepat berbanding dengan penyelidikan terdahulu. Pelantar ujian aliran udara kos rendah yang sedia ada telah direka bentuk dengan penambahbaikan pada bahagian tertentu dengan keupayaan untuk menganalisis pelbagai sampel menggunakan konfigurasi Arduino. Ini boleh menyumbang untuk meningkatkan kesedaran tentang pelbagai jenis gentian semula jadi dan, seterusnya, mengehadkan penggunaan gentian sintetik dalam industri. Objektif kajian ini adalah untuk mereka bentuk penambahbaikan pada pelantar ujian aliran udara sedia ada. Seterusnya, untuk membangunkan pelantar ujian yang lebih baik menggunakan mesin pencetak 3D. Akhir sekali, untuk menganalisis rintangan aliran udara pada ketebalan berbeza gentian kulit dalam durian menggunakan pelantar ujian aliran udara dengan bantuan konfigurasi Arduino. Untuk mencapai objektif pertama projek ini, iaitu untuk mereka bentuk penambahbaikan pada pelantar ujian aliran udara sedia ada, carta morfologi, reka bentuk konsep dan kaedah Pugh telah digunakan. Reka bentuk konsep 3 dengan jumlah skor tertinggi dalam kaedah Pugh telah dipilih sebagai reka bentuk konsep terbaik berbanding reka bentuk lain. Selain itu, bagi mencapai objektif kedua iaitu pembangunan pelantar ujian yang ditambah baik menggunakan mesin cetak 3D, ia boleh dilakukan dengan menggunakan mesin cetak 3D Pensinteran Laser Terpilih Farsoon 402P (SLS) yang terdapat di universiti. Tambahan pula, untuk mencapai objektif ketiga projek ini iaitu menganalisis rintangan aliran udara pada ketebalan gentian kulit dalam durian yang berbeza, ia perlu dianalisis melalui ujian apabila udara melalui spesimen menggunakan pelantar ujian aliran udara. Bagi mendapatkan nilai tekanan pembezaan dan halaju keluaran dengan tepat melalui ujian ini, ia boleh diperolehi dengan bantuan konfigurasi Arduino dan anemometer. Keputusan menunjukkan halaju keluaran menjadi lebih rendah, manakala tekanan pembezaan menjadi lebih tinggi apabila ketebalan spesimen meningkat. Walau bagaimanapun, rintangan aliran udara boleh didapati daripada pengiraan manual. Berdasarkan keputusan, spesimen dengan ketebalan yang lebih tinggi akan menghasilkan kerintangan aliran udara yang lebih rendah. Data kerintangan aliran udara ini, sama ada pada kelajuan rendah atau tinggi, adalah signifikan selepas dianalisis menggunakan kaedah regresi linear. Jadual analisis varians dengan nilai P kurang daripada 0.05 ditunjukkan dalam analisis kaedah statistik ini pada kedua-dua kelajuan. Oleh kerana struktur mikro dan susunan gentian kulit dalam durian yang besar, ia telah dipilih sebagai akustik gentian asli untuk digunakan untuk penyelidikan ini. Dalam kes ini, kerintangan aliran udara yang lebih rendah dianggap sebagai pekali penyerapan bunyi yang terbaik kerana jumlah halaju bunyi yang paling sedikit boleh menembusi gentian.

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Last but not least, I want to express my heartfelt thanks to my loving father, Zaiham Bin Awang @ Zainon, for his support and encouragement throughout my life. My unending gratitude to Roziah Binti Daud, my mother, for her tolerance and understanding. I'd also like to express my gratitude to my loving family for their unwavering support, love, and prayers. Finally, thank you to all my friends who had provided me the assistance, support and inspiration to embark on my study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

3D	-	Three-dimension
SLS	-	Selective Laser Sintering
DP, Δp	-	Differential Pressure
v, u, $\bar{v}$	-	Velocity
h	-	Thickness
σ	-	Airflow Resistivity
Pa	-	Pascal
m	-	Meter
V	-	Average Velocity
Q	-	Volumetric Airflow Rate
A	-	Cross-sectional Area of material perpendicular to the flow
Rf	-	Airflow Resistance
Rs	-	Specific Airflow Resistance
s	-	Second
L/s	-	Liter per second
AMCA	-	Air Moving and Conditioning Association
p	-	Density
C	-	Flow Coefficient
AC	-	Alternating Current
DC	-	Direct Current
CAD	-	Computer-aided Design
FDM	-	Fused Deposition Modelling
IDE	-	Integrated Development Environment
CAD	-	Computer-aided Design
FDM	-	Fused Deposition Modelling
PSM	-	Project Sarjana Muda
KB	-	Kilobyte
Mm	-	Millimeter
W	-	Watt

Kg	-	Kilogram
SLA	-	Stereolithography
UV	-	Ultraviolet
µm	-	Micrometer
L/D	-	Ratio
mm/s	-	Millimeter per second
AM	-	Additive Manufacturing
I/O	-	Input / Output
Rpm	-	Rotation per minute
m/s	-	Meter per second
kPa	-	Kilopascal
Fpm	-	Feet per minute
<	-	Less than
≤	-	Less thn or equal
RE (L)	-	Result of Airflow Resistivity for Low Speed
RE (H)	-	Result of Airflow Resistivity for High Speed

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background Study

An airflow resistivity is a crucial parameter which characterizes the acoustic property of the material. Several studies have been done in this field which proposed the relationship between this parameter that related with the thickness and the density of the material. The discovery shows that airflow resistivity is related to the acoustic property of the material which makes it possible to calculate both airflow resistance and the specific airflow resistance easily from acoustic data such as the transmission losses or coefficient of absorption. The flow resistivity reflects the permeability of air through porous material and it is defined as the airflow resistance within a unit of thickness as shown in Figure 1.1 (Geyer et al., 2017). The higher the airflow resistivity, the lower the permeability of the air. The pressure between both sides of the porous sample to the speed of air flow is referred as pressure different. According to the Figure 1.1, airflow resistivity evaluates how air flows through a porous sample and the resistance it encounters as it moves through a structure.

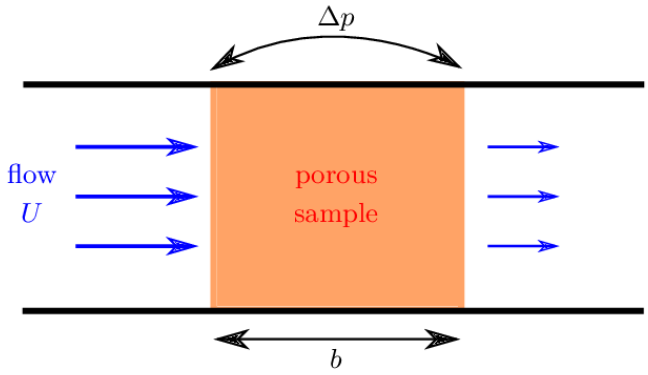

Figure 1.1 Air Flows Through a Porous Sample (Geyer et al., 2017)

1.2 Problem Statement

Natural fiber is a fiber that can be categorized as a porous material. With the most up-to-date technology, there are numerous underused of natural fiber, despite the fact that they have several benefits and are safe to use. In reality, these materials have their unique acoustic properties that require further study and testing before they can be used as an alternative option for acoustical applications in the future. By doing so, it may be possible to expand the scope of acoustical research. As there are many fields in acoustics that are related to natural fiber, such as aeroacoustics, musical acoustics, environmental noise, and soundscapes. In this study, the variety types of natural fiber can be process into porous specimen as different type of materials have different airflow absorption and volume of airflow rate for the airflow resistivity testing. The airflow resistance of porous materials indicates, in an indirect manner based on their structural properties. So, in order to achieve a better result while testing airflow resistivity, the technique of preparing the specimen is essential. This is due to the fact that the thickness and density of the natural fiber are also significant in analyzing the outcome since the chance of failure is higher when the specimen is prepared with properties that are not appropriate for testing.

It can be utilized to develop relationships between the material of sample and certain of their acoustic property, such as transmission loss, coefficient of absorption, and so on. Therefore, it can be useful in relating some of the acoustic property of material to their structure and their method of preparation is depends on the purpose required. Since there are nowadays various studies in the field of air flow that illustrate the proper use of flow meters, digital anemometer or even microcontroller which are essential and relevant in a wide range of industries. In order to provide and use in further study with exposure to these types of devices and how they work, a test rig has been improved and developed with a

microcontroller and able to interchange a variety of flow meters to broaden the knowledge of the various types of measuring devices available.

Furthermore, the use of porous materials as the sound absorption is well established. However, the information of flow resistivity on the materials that is required to adequately define their acoustic performance. On the other hand, the concept of flow resistivity is quite outdated and well acknowledge, and it is frequently mentioned in the literature. Meanwhile, there is no systematic review and compilation of its uses has been attempted previously. This might happen because there are numerous gaps in the knowledge that have prohibited such an approach (Bies and Hansen, 2017). So, this might help in gathering comprehensive study more details about the airflow resistivity and to demonstrate the effectiveness of its uses in solving a variety of acoustics property using a test rig.

1.3 Research Objective

The purpose of this project is to study related to airflow resistivity system with rapid prototyping on acoustic properties of the material. From that, the experiment can be carried out using Arduino configuration to test the airflow resistivity of the natural fiber using the air flow test rig. Specifically, the objectives of this project are as follows:

- To design an improvement on the existing airflow test rig.
- To developed the improved test rig using 3D printing machine.
- To analyze the airflow resistivity on different thickness of the durian inner peel fiber using airflow test rig with the aid of Arduino configuration.

1.4 Scope of Research

In order to provide and use in further study with exposure to these types of devices and to be more efficient, a low cost test rig has been improved and developed with the ability to analyze the differential pressure and the air velocity on different thickness of natural fibers in order to broaden the knowledge with the aid of a microcontroller which is Arduino that attach to it. So, firstly design an improvement on a part that needs to be improved using SolidWorks software. The best conceptual design has been chosen based on several criteria. Then, proceed with printing the best conceptual design using selective laser sintering (SLS) 3D printer machine available in the university due to limitation on budget for this project. Next, run the testing on the improved test rig and proceed with analyze the output that presented by the Arduino and anemometer to study the airflow resistivity based on the thickness of the sample specimen, which is durian inner peel fiber.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction of Design Research

This chapter discusses work that related to the background and research. There are several research studies that have been discussed in the study of literature review that can be compared to this project. In addition to this chapter, journals, books and articles can be used as guidance. Research in literature also provides a systematic method and help in making this undertaking a success.

2.2 Definition of Airflow Resistivity

An airflow resistivity is one of the important parameters used to describe the acoustic property of fibrous and porous materials, which quantifies the ability to oppose resistance to the motion of air particles inside the material per unit length (Schiavi et al., 2019). Xue et al. (2017) define that resistivity as a pressure ratio of unit thickness to airflow velocity in the cylinder tube that is vertical to the air flow in steady state. Fibrous material is generally known as the materials that are made up of fibers. It can be category as anisotropic. It means that any type of fibrous material has a unique physical attribute that can be computed in a variety of ways to get a specific value, such as the resistivity of air flow based on the direction of air flow through the material or sample. The flows are being considered as a steady flow and non-pulsating (Sadouki et al., 2015). The resistivity of airflow can be calculated through an experiment in which a sample specimen of fibrous material is placed in a tube in vertical and the air flow is given to passed through the sample (Yang et al., 2018). The resistivity to static air flow, which is often to reduced resistivity, is also one of the two parameters used to express the acoustic property of porous fibrous materials, along with open porosity.