**ACOUSTIC CHARACTERISTIC OF PINEAPPLE LEAF FIBER**

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**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

# ACOUSTIC CHARACTERISTIC OF PINEAPPLE LEAF FIBER

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**This report is submitted**
**in fulfillment of the requirement for the degree of**
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**Faculty of Mechanical Engineering**

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## SUPERVISOR'S DECLARATION

I have checked this report and the report can now be submitted to JK-PSM to be delivered back to supervisor and to the second examiner.

Signature : ……………………………..

Name : ……………………………..

Date : ……………………………..

# DEDICATION

To my beloved mother and late father

# ABSTRACT

The current acoustic absorbers are made from synthetic materials is still applied comprehensively in building industry. These non-biodegradable materials are not only causing global warming and pollutions to the environment by increasing the $CO^2$ in the atmosphere during its production, but it also give negative effect to the human. Thus, researchers have their attention to find sustainable and eco-friendly materials which have the potential to replace the synthetic materials to be an alternative sound absorber. Pineapple leaf fiber is biodegradable material and it is available in plenty quantity as agricultural waste in Malaysia. In this study, the sound absorption of pineapple leaf fiber (PALF) is investigated to be a sustainable acoustic material. A samples sound absorber from pineapple leaf fiber is fabricated with different thickness, masses are tested using impedance tube according to ISO 10534-2 to measure the sound absorption coefficient. The effects of fiber density (mass), thickness, air gap and fabric on sound absorption performance are investigated. The performance of the sound absorption coefficient increase at the high frequency region due to the increment of the fiber density. The increment of thickness, application of air gap and added a layer of fabric at the samples increase the sound absorption coefficient especially at the lower frequency region. From the experimental result, samples at thickness 30 mm to 50 mm showed a good sound absorption performance where the average absorption coefficient is 0.98 in average frequency above 1000 Hz.

# ABSTRAK

*Penyerap akustik semasa diperbuat daripada bahan-bahan sintetik masih digunakan secara menyeluruh dalam industri pembinaan. Bahan-bahan ini tidak terbiodegradasi bukan sahaja menyebabkan pemanasan global dan pencemaran kepada alam sekitar dengan meningkatkan CO2 dalam atmosfera semasa pengeluaran, tetapi ia juga memberi kesan negatif kepada manusia. Oleh itu, penyelidik mempunyai perhatian mereka untuk mencari bahan mampan dan mesra alam yang mempunyai potensi untuk menggantikan bahan-bahan sintetik untuk menjadi penyerap bunyi alternatif. serat daun nanas adalah bahan mesra alam dan ia boleh didapati dalam kuantiti yang banyak sebagai sisa pertanian di Malaysia. Dalam kajian ini, penyerapan bunyi Pineapple Leaf Fiber (PALF) disiasat menjadi bahan akustik yang mampan. Sampel penyerap bunyi daripada gentian daun nanas adalah rekaan dengan ketebalan yang berbeza, berat diuji menggunakan tiub galangan mengikut ISO 10534-2 untuk mengukur pekali penyerapan bunyi. Kesan ketumpatan serat (jisim), ketebalan, ruang udara dan kain prestasi penyerapan bunyi disiasat. Prestasi peningkatan pekali penyerapan bunyi di rantau kekerapan yang tinggi disebabkan oleh kenaikan ketumpatan gentian. Peningkatan ketebalan, penggunaan ruang udara dan menambah lapisan kain pada sampel meningkatkan pekali penyerapan bunyi terutama di rantau frekuensi yang lebih rendah. Dari hasil eksperimen, sampel pada ketebalan 30 mm hingga 50 mm menunjukkan prestasi penyerapan bunyi yang baik di mana pekali penyerapan purata 0.98 dalam kekerapan atas rata-rata 1000 Hz.*

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**CHAPTER 1**

**INTRODUCTION**

## 1.1 BACKGROUND

Effective sound control can be attained with a complete understanding of sound phenomenon (Zhu et al., 2014). The sound energy that flow to the wall it can be either reflected back or absorb inside the wall. In order to reduce the sound energy, it must be absorb the sound energy. The sound energy will circulate throughout the building or any transmission path because the sound energy does not remain in the room. Reverberation time must be considered in room or in parts of the building where noise has to be reduced to reduce the echo. The wall of the building or room and around the structure must be containing the material that can absorb the sound energy in order to reduce noise in the building. Besides, there are need to find and choose properly material that capable to reduce or absorb the noise energy. Sound absorbing material will minimize reflection of the sound energy by converting it to heat through some frictional process in the absorber. Commonly, the sound absorbing material applied to walls and ceilings to reduce the noise and thus minimize sound reflection at the walls and it will reduce the sound level. Brickwork, concrete and sheet metal are good sound insulation because of the high mass per unit area but it have hard sound reflecting surfaces so it is still poor absorbers of sound. Based on Figure 1.1, it uses the glass wool at the wall to absorb the sound energy and Figure 1.2 shows the foam glass use at floor. Synthetic materials such as glass wool and foam glass are commonly used as sound absorber and these materials are found to be harmful to human health (Asdrubali, 2006).

Figure 1.1: Glass wool use at wall

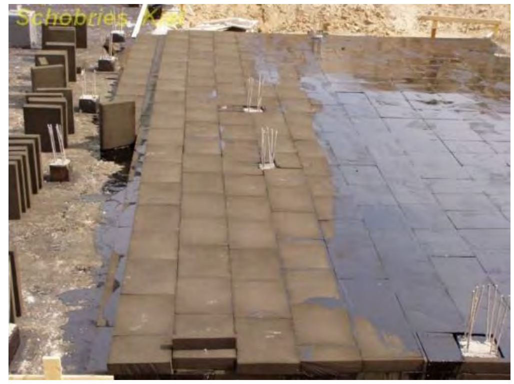


Figure 1.2: Foam Glass use at floor

This synthetic material is not only harmful to human health but also cause pollution and global warming. Synthetic material also is more expensive material to use for sound absorption. Thus, researcher need to change the material used for sound absorption to the natural material which is it is more safe to use, easy to conduct and easy to get.

## 1.2 PROBLEM STATEMENT

Fiber synthetics as sound absorbing materials are commonly used because of their good performance and low cost and always used for thermal and sound insulation (Asdrubali, 2006). Even though the synthetic material is good for sound absorption and low cost but it also have negative side which is it can be harmful for human health for example lung alveoli, and cause the skin irritation. It also contributes to the discharge of carbon dioxide, methane and nitrous oxide (Arenas et al., 2010). Compared to the natural material which is have very low toxicity and the production does not effect to the environment. Due to the negative impact of using a synthetic material, the natural material has been widely used to produce sound absorption. There are many natural fiber ended up as wastes. One of the examples is pineapple leaf as shown in Figure 1.3. There has been a lack discussion on this natural fiber, particularly on its potential utilization as sound absorber. For this research, pineapple leaf fiber (PALF) is studied as alternative natural sound absorber.

Figure 1.3: Pineapple Leaf

## 1.3 OBJECTIVE

The main objectives of this project:

1) To extract fibers from the raw pineapple leaf.
2) To construct a different thickness and density (mass) samples of sound absorber panel from pineapple leaf fibers.
3) To measure the absorption coefficient of the fibers.

## 1.4 SCOPE



The focus of this study is to determine the acoustic performance of the pineapple leaf fiber only. In real life the sound energy come from any angle and any side, but in this study focuses on sound energy normal to the panel. The other properties of the pineapple leaf fiber for example structural strength, thermal conductivity and fire retardant are excluded during evaluating sound absorption coefficient.

**CHAPTER 2**

**LITERATURE REVIEW**

## 2.1 Porous Material

One of the methods to reduce the sound energy uses a sound-absorbing material. Sound absorbing material can absorb the sound energy which is sound energy less reflect through wall. Sound absorption material is classified three types which are porous, resonator and panel. This three type based on theory is transforming from sound energy to thermal energy (Lee. et al., 2003). A porous material is the material that can absorb the sound energy which is have high sound absorption coefficient. Porous absorber has a high absorption coefficient compare to Helmholtz resonator and panel resonator. Figure 2.1 shows the comparison sound absorber between porous, panel and cavity Helmholtz.



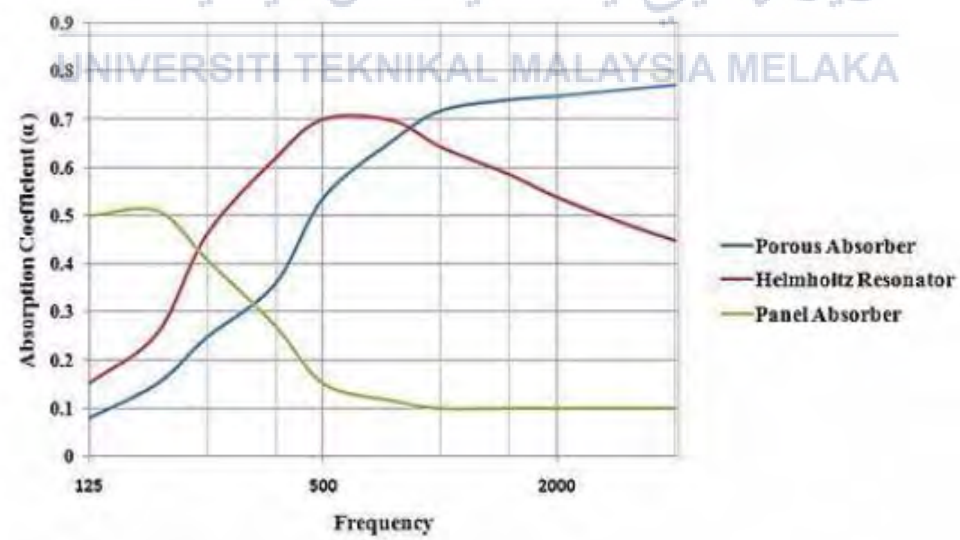



Figure 2.1: Variation of absorption with frequency for porous, panel and cavity Helmholtz

Porosity is known as ratio of the volume of void to the total volume of samples. There are three methods to determine the porous material which is dynamic, static method or simple calculation based on the density of the material (Wassilieff, 1996). A porous material is a solid that contain cavities, so the sound energy can flow through them. Porous material has a pore or closed pores but the open pores are more efficient compare to closed pore because the sound energy can flow through them but for the close pore the sound wave cannot flow. The open pore can influence the efficiency of the absorption of sound. The frictional force and the viscous will losses between the air in the pores (Kuczmarski. et al., 2011). According to Soto et al., (1993) using porous material in automotive industry for sound absorption result shows that the material that biggest pore size which is 1.1 mm with the thickness 5 mm is the most effective for sound absorption compare to the small pore size. Besides, the material that with same thickness but small pores size with a lot of interconnected cells is also good sound absorption at low frequency. Figure 2.2 show that the structure of the interconnected cell.



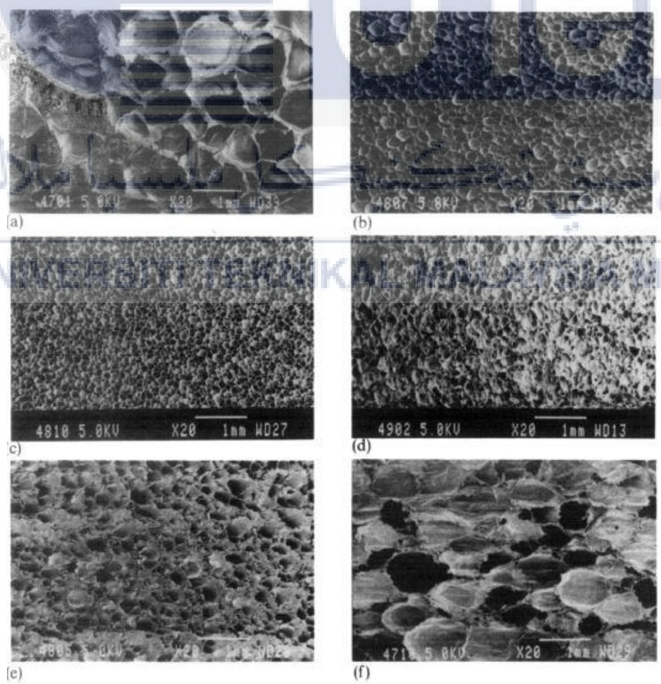



Figure 2.2: SEM micrographs of polyolefin closed cell foams (x20).

Same goes to porous ceramic material, according to Cuiyun et al., (2012) higher porosity could increase the highest sound absorption coefficient and increase the thickness of material improves the sound absorption at the low frequency. The comparison between porous zeolite and glass wool with different thickness 15 mm and 25 mm show that increases of the thickness of the sample could increase the sound absorption at the low frequency. The porosity of the porous zeolite is increase from 68.59% to 70.69% show that increase the sound absorption coefficient from 0.96 – 1.0. Figure 2.3 shows sample of the porous zeolite.

Figure 2.3: Sample of porous zeolite (Cuiyun et al., 2012)

Another porous material that has been done is comparison with glass wool and foam (Ovidiu et al, 2014). In this study, it shows that the number, size and pore type is the important factors need to be considered on the sound absorption in porous material. The surface of the porous material must have enough open pores in order the sound energy move through it. Flexible Polyurethane Foam (FPF) open pores with thickness 30 mm and Rigid Polyurethane Foam (RPF) closed pore with rate >90% with same thickness were analyzed. Figure 2.4 show the structure of the surface of the FPF and RPF.  The frequency range 1250 Hz to 1600 Hz of the two material have a same value of sound absorption coefficient. Generally, it can observe that the material that opens pores has good sound absorption compare to closed pores material.

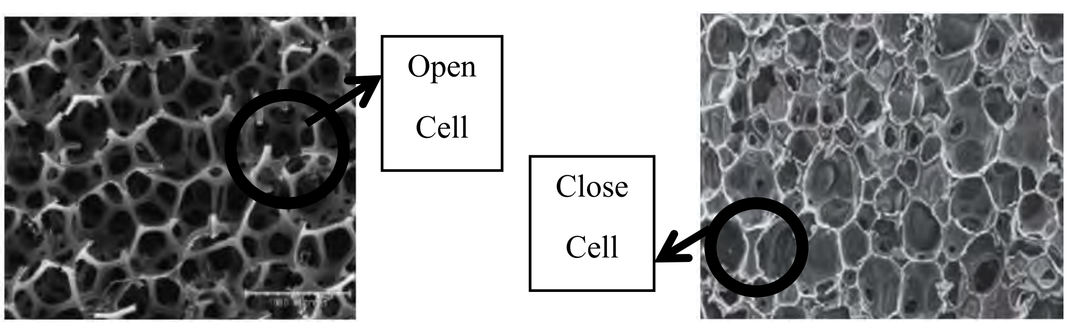



Figure 2.4: The cell structure of the RPF (left) and FPF (right) (Ovidiu et al, 2014)

## 2.2 Mechanism of Sound Absorption in Fibrous Materials

The sound energy that absorb by absorptive material is convert to heat. There are many authors and research has been done explained about the mechanism of the sound absorption (Delany et al., 1970; Bies et al., 2003; Wang et al., 2001; Barron 2003). According to Beranek, (1992) there are three mechanism of sound absorption, first is friction loss. Friction loss occur when the sound energy enter the porous material, the air molecule oscillate in between the porous material with the frequency of the sound energy. Next is momentum loss, change flow direction of sound energy due to fiber or irregular pores, this resulting momentum loss of sound wave. Lastly is change of temperature. Due to sound energy, the air molecules in the pores go through compression and relaxation. At low frequencies region, because of long travel, large surface to volume ratios and high heat conductivity of fibers, heat exchange occurs isothermally because of contacting between fiber and wave propagation. For high frequency region, compression takes place adiabatically which is there is no heat exchange occur during the travel. This is resulting to loss of sound and if the sound energy propagates parallel to the fibers, the sound energy losses up to 40% (Beranek, 1992).

## 2.3 Factors Influence Sound Absorption

### 2.3.1 Thickness



The thickness of the absorbent porous material has a relationship with the sound absorption at the low frequency. The thicker material the higher value of sound absorption coefficient and the thicker material are good absorption at low frequency compare to higher frequency range (Samsudin et al., 2016).

ALRahman et al., (2014), in this study comparison material between date palm fiber (DPF) and oil palm fiber (OPF) to compared sound absorption performance with different thickness which is 30 mm and 50 mm. Figure 2.5 shows the sample of fiber. Increase the thickness of the fiber, it increases the performance of the sound absorption but the peak frequency for both fiber shifted to low frequency region. Date palm fiber shows high sound absorption coefficient compare to oil palm fiber. For DPF with thickness 30 mm and 50 mm show 0.83 and 0.93 for maximum absorption at 2500 Hz and 1300 Hz, for OPF the highest absorption 0.60 and 0.75 at frequency 3500 Hz and 2000 Hz for thickness 30 mm and 50 mm.

Figure 2.5: Test samples of date palm fiber (left) and oil palm fiber (right) (ALRahman et al., 2014)

Masrol al., (2013), in this research investigate about the sound absorption of palm oil male flower spikes (POMFS) strengthened with polyutherene composite with different of thickness 8 mm, 25 mm, 35 mm. There are 5 different of POMFS, polyutherene with the ratio 5:95, 10:90, 15:85, 20:18 and 25:75. 5 % of POMFS shows that highest of the sound absorption coefficient by thickness 25 mm panel with 0.36 at 5800 Hz. The highest sound absorption coefficient for 10% POMFS is 0.37 at 6000 Hz for 8 mm thickness panel and for 25 mm thickness 15% POMFS shows highest absorption is 0.86. At the frequency 4100 Hz shows 20% POMFS is maximum absorption value is 0.78. Lastly, 25% of POMFS at the frequency 4100 Hz shows the sound absorption coefficient is 0.8.



Another study of factor influence sound absorption, Fouladi et al., (2013) by using coconut coir, corn, grass and sugar cane fibers with different thickness has been investigate in this research. Figure 2.6 and 2.7 show the coir fiber and corn fiber. The results show that the sound absorption coefficient (SAC) for corn fiber, highest absorption for corn fiber is 0.7 at 3000 Hz for 1 cm thick and with the increases of the thickness from 1 cm to 2 cm show that the peak frequency shifted from lower range to higher frequency range with the SAC 0.9 at 4000 Hz. For grass fiber, increases the thickness show improvement of SAC from 0.46 for 1 cm to 0.98 for 2 cm thick and peak frequency has been shifted from higher frequency range to lower frequency range. For sugar cane fiber, peak absorption remains constant after increase the thickness which is 0.88. The peak frequency shifted to lower frequency range when the thickness increases. Lastly, SAC of coir fiber increase from 0.46 at 4000 Hz to 0.97 at 2000 Hz from 1 cm thick to 2 cm thick of coir fiber.

Figure 2.6: Coir fiber in disk form Fouladi et al., (2013)

Figure 2.7: Corn fiber in disk form Fouladi et al., (2013)

Next, the study by Al-Rahman et al., (2012) investigates effect of thickness and compression of innovative material from date palm fiber (DPF) on sound absorption. 20 mm, 30 mm, 40 mm, and 50 mm thick tested by low and high frequency. Result show that increases the thickness of sample increase the absorption for lower range frequency. For 20 mm thick, maximum absorption is 0.64 at 3884 Hz, for 30 mm thick peak frequency is 0.83 from 4978 Hz to 5000 Hz. For 40 mm and 50 mm, the highest absorption at frequency 4950 Hz to 5000 Hz is 0.83 and 0.86 respectively.



Zulkifli et al., (2010) in research about the effect of porous layer backing (PLB) and perforated panel (PP) with different thickness of coconut coir fiber (CCF) 10 mm and 20 mm. Figure 2.8 show the sample, fiber and perforated panel. The highest absorption for 20 mm CCF without PLB and PP attained 0.83 at 3784 Hz and for 10 mm samples shows highest absorption of 0.39 at 5000 Hz. For the samples backed with layer of Woven Cotton Cloth (WCC), it shows the increases of peak absorption. For 10 mm CCF with WCC layer backing attained highest absorption of 0.96 at 3800 Hz and for 20 mm CCF with WCC achieved 0.97 at frequency range 2750 Hz-2825 Hz. The peak absorption was shifted to lower frequency range and remains constant when the sample attached with perforated panel (PP).

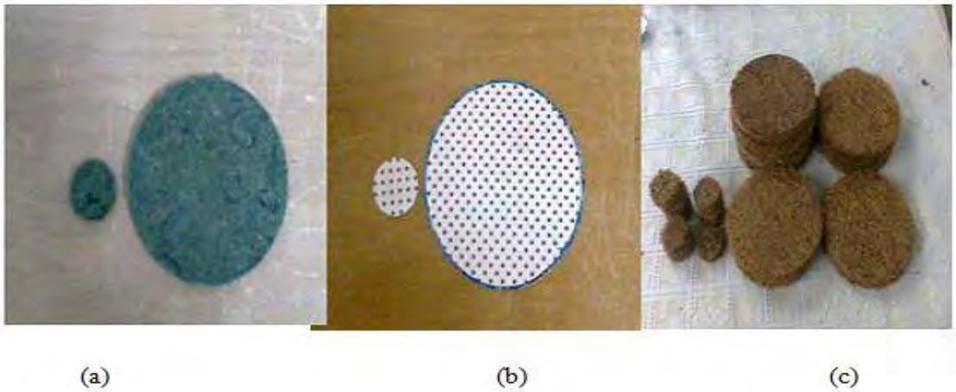


Figure 2.8: Test samples (a) porous layer (b) perforated panel (c) coconut coir fiber (Zulkifli et al., 2010)

Ersoy and Kucuk, (2009), research about tea leaf fiber (TLF) with different thickness 10 mm, 20mm and 30 mm. 10 mm thick TLF attained highest SAC of 0.26 in the frequency range 4000 Hz-6300 Hz. For 20 mm thick TLF show it peak absorption of 0.60 at 6300 Hz and for 30 mm thick TLF sample achieve 0.7 at 5600 Hz. For the sample backed with woven cotton cloth (WCC), 10 mm TLF sample shows that peak absorption is 0.8 at frequency range 5500 Hz-6300 Hz. For 20 mm and 30 mm thick, sound absorption coefficient value gradual increase at lower frequency region.

Another research about the sound absorption influence by the thickness of the material is research by Putra et al., (2013) using paddy fibers (PF) as sustainable acoustic material. Figure 2.9 show the sample of paddy fiber. PF samples were prepared with different thickness and different weight which is 10 mm and 20 mm and weight with 2 g and 4 g. For the samples PF with thickness 10 mm shows good performance with sound absorption coefficient (SAC) more than 0.5 above 3000 Hz and for the sample with 20 mm thickness it show that the absorption coefficient increase below 3500 Hz. Increasing the thickness of the samples, the sample may have more open pores which is the sound energy with high frequency can propagate easily (Putra et al., 2013).

Figure 2.9: The sample of paddy fibers Putra et al., (2013)

Ismail and Ghazali, (2010) research about Arengga Pinnata fiber (APF) with different of thickness that is 10 mm, 20 mm, 30 mm and 40 mm. From the result, it can be concluded that the thicker sample is a good sound absorption compare to the thinner sample. For the samples 10 mm, 20 mm and 30 mm, sound absorption coefficient (SAC) is less than 0.1 at frequency range 0-1000 Hz. Peak absorption coefficient for 10 mm, 20 mm and 30 mm is 0.3, 0.55 and 0.7 respectively. For APF with 40 mm, the highest absorption coefficient is 0.88 at frequency 5000 Hz.

Lastly, the research by Koizumi et al., (2002) about bamboo fibers (BF) with different thickness that is 25 mm, 50 mm and 75 mm. The thicker BF with 75 mm thick attained a highest absorption is 0.98 at frequency in range 700 Hz-1000 Hz. For 50 mm thick samples, the peak absorption is 0.96 in between 1400 Hz-1500 Hz and lastly for 25 mm the highest absorption is 0.89 at frequency between 2800 Hz-3000 Hz. The thicker BF absorbs more sound energy at lower frequency range and the thinner BF is good for higher frequency.

As the conclusion, all researched done by researcher's shows the same result and pattern which is absorption performance influence by thickness of the material or sample. The thicker samples show that can absorb more energy at lower frequency region and thinner samples absorbed more sound energy at higher frequency region. According to AL-Rahman et al., (2014), the thicker sample absorb more sound energy because the sound energy need to travel more distance in the structure of the samples which is can loss it energy.

### 2.3.2 Density

The other important factor that influences the sound absorption behavior is density of the material (Seddeq, 2009). The material that has more fiber per unit area in the sample cause larger density. The larger the density of the material, more energy sound energy that can be absorb because of the more surface frictional between the sound wave and the fiber. Thus, it will increase the sound absorption coefficient of the material.

Recent research by Al-Rahman et al., (2012) investigates about sound absorption of date palm fiber (DPF) with different density. The samples were divided into two, first are higher density and second are lower density. The higher density group is 10kg/m$^3$ and 11 kg/m$^3$ and for the lower density group are 4.76 kg/m$^3$, 7.15 kg/m$^3$ and 9.2 kg/m$^3$. DPF with 11 kg/m$^3$ show the highest absorption of 0.83 at 2000Hz and for the sample 10 kg/m$^3$ is achieved 0.6 at 2000 Hz. For the low density group DPF samples with densities 4.76 kg/m$^3$, 7.15 kg/m$^3$ and 9.2 kg/m$^3$, the highest SAC is 0.84 in between 2443.75 Hz-2587.5 Hz.

Tea leaf fiber by Ersoy and Küçük, (2009), investigate three different densities on sound absorption. The samples were prepared with density from 25.35 kg/m$^3$ to 27.5 kg/m$^3$. Peak absorption achieved by the samples with density 27.5 kg/m$^3$ with sound absorption coefficient (SAC) of 0.7 at 5600 Hz and for the sample with density 25.35 kg/m$^3$ attained SAC 0.6 at frequency 6300 Hz. The sample with density of 25.358 kg/m$^3$ and with density 25.35 kg/m$^3$ is the lowest SAC which is 0.26 at 4000 Hz to 6300 Hz.

Koizumi et al., (2002) develop of sound absorbing materials using natural bamboo fibers with different of density. Bamboo fiber samples were prepared with densities 80 kg/m$^3$, 120 kg/m$^3$, 160 kg/m$^3$. Results show that when the density of the material increases, more sound energy that can be absorbed. High density bamboo fiber board (HDBFB) which formed using 10% of binding materials under hot press molding also tested in this research. There are four different density of HDBFB are 400 kg/m$^3$, 500 kg/m$^3$, 600 kg/m$^3$ and 700 kg/m$^3$. The samples of HDBFB including with 50 mm thick of air gap. The result show SAC value for HDBFB decreases when the density increases at high frequency range. This is due to the cavities between the fiber are closed and cause the less frictional effect between the fiber and sound wave.

Putra et al., (2013) in their research using sugarcane waste as acoustic absorber. The samples were prepared with different mass having 1 g and 3 g weight fiber that backed with binder. Figure 2.10 show the sample of sugarcane fiber. Results show that for the sample with 1 g fibers, peak absorption is 0.5 at 3500 Hz and for the 3 g fiber achieved peak absorption 0.7 at 2500 Hz-3000 Hz. From the result, it shows that the more fibers give better sound absorption. The sample that denser, the arrangement of the fiber is too close and compact. So the sound energy loses energy during the travel among the fiber.

Figure 2.10: Sample of sound absorber from sugarcane fibers Putra et al., (2013)

Use an oil palm fiber as soundproofing material by Or et al., (2015) to investigate the effect of mass and air gap to sound absorption coefficient (SAC). The samples oil palm empty fruit bunch (OPEFB) fibers were prepared with different mass, 1, 2, 3, 4, 5, 6, and 7 grams. Figure 2.11 show the sample of the oil palm fiber with different thickness. The result shows that, mass of 2, 3, 4 and 5 grams shows a good performance of absorption. The sound absorption coefficient is more than 0.5 at frequency above 2000 Hz (Or et al., 2015). For the sample with 6 and 7 gram, show the absorption coefficient less than 0.5. This is because; the sample that high density can increase the porosity of the fibers, so the sound energy cannot pass through the fiber.

Figure 2.11: The samples of oil palm fiber (Or et al., 2015)

As the conclusion, the denser material absorbs more sound energy compare to less dense materials (Samsudin et al., 2016). Density is high when the number of fibers increases per unit area, thus, the sound energy loss more due to surface friction increase. However, the performance of sound absorption reduces due to higher density. Material that more compact and higher in density will affect the performance of the sound absorption.

### 2.3.3 Fabric

Introducing the fabric to the sound absorber material can improve the absorption coefficient of the material. Research by Putra et al., (2013), introducing the polyester fabric at the front and the back of the paddy fiber sample increase the sound absorption coefficient. Figure 2.12 show the sample of paddy fiber attached with polyester fabric. The peak absorption coefficient shifted to the lower frequency after introducing the polyester fabric. The absorption coefficient for polyester fabric at the front and back of the surface sample shifted to the lowest frequency compared to fabric at the front and the back only. The absorption coefficient for the sample with both side fabric achieved ($\alpha < 0.5$) at the frequency 700 Hz and peak absorption coefficient is 0.97 at frequency 2500 Hz to 3300 Hz. The absorption coefficient for sample with fabric at the front surface is higher compared to sample with fabric at the back surface. This is due to the sound energy had been start to lost at the front of the sample which is lost in the cotton's fiber. The sample without applying the fabric achieved peak absorption only 0.8 at the frequency 4000 Hz and achieved 0.5 at the 2800 Hz. As the conclusion, applying the fabric improve the sound absorption coefficient of the sample compared to without fabric.

Figure 2.12: Sample of the paddy fiber attached with polyester fabric

### 2.3.4 Compression

Factor compression decrease the sound absorption coefficient, a research by Castagnede et al., (2000) explained that samples or fibers that undergo compression is make the fibers closer each other without change in fiber size. Due to compression of fiber, the thickness decrease. Besides, the author also found that compression of fiber increase the tortuosity and airflow resistivity and decrease the porosity and thermal characteristic length Castagnede et al., (2000). As the conclusion, the sound absorption drop because of the decreases of the samples thickness.

### 2.3.5 Surface Treatment

Commonly, the acoustical materials are used in the building and these materials act as interior design so the surface of the material should have good appearance and good light reflecting. According to Davern, (1970), the acoustical materials are coated with paints when use for inside the buildings. Due to the layer of paint, more open structure of the materials is close. According to Price et al., (1967), the layer of paint coating should be very thin that applied at the surface of the absorbent materials. From the research, it shows that the material coated with more layer of paint the absorption coefficient decreases and the material that untreated surface shows good sound absorption coefficient compare to the absorbent material that coat with paint. The material that coated shows the absorption coefficient shifted toward low frequency and by spraying it can increase the absorption coefficient. As the conclusion, the coating layer close the open-structure of the materials and the very thin layer of paint should be applied by using spray-gun.

## 2.4 Summary

As the conclusion, the porous material can absorb the sound energy which is can reduce the amount of sound energy that can reflect from the wall. In the porous material, the sound energy converts to the heat. The sound energy loss in the porous material occur due to three mechanism which first is friction loss, second is momentum loss and lastly is change of temperature. In order to increase the performance of the sound absorption there are several methods to increase the sound absorption coefficient of the material. The thickness of the samples can enhance the performance of the absorption because the sound energy long travels in the sample and the friction between the sound energy and absorptive material increase. Next is, the density of the material also can increase the performance due to the high flow resistivity of the samples. The higher the flow resistivity of the samples, more difficulty of sound energy to penetrate in the sample. The compression of the material can decrease the performance of the absorption due to the fibers/material closer/packed each other. Lastly, the surface treatment of the samples, normally the material coated with paint which is can close the open pores of the material. More layer of paint can decrease the performance of the sound absorption.

# CHAPTER 3

# METHODOLOGY

## 3.1 Introduction

In this chapter describes the methodology used in this project to obtain sound absorption coefficient of natural pineapple leaf fiber (PALF). The flow chart of the project is shown in Figure 3.1. From the figure 3.1, this project started by preparing the raw material which is pineapple leaf. The pineapple leaf then is extracted using machine called "*Mesin Pemacah Daun Nenas"* then the fiber is treating using alkaline (NaOH) treatment for 1 hour. The treated fiber then is fitted in the aluminium web casing to fabricate the samples with different of thickness and density of fibers. Lastly, the samples are tested using impedance tube to obtain the sound absorption coefficient of the pineapples leaf fiber.



## 3.2 Preparation of Raw Material

For this study, the main raw material is pineapple leaf. Pineapple leaf comes from pineapple plant, Ananas comosus, from Bromeliaceae family (Sapuan and Khalina, 2009). Nowadays, in Malaysia the pineapple only focus to and foodstuffs and pineapple leaf leave as waste materials or burnt it and this is cause to air pollution (Abdul et al., 2006).

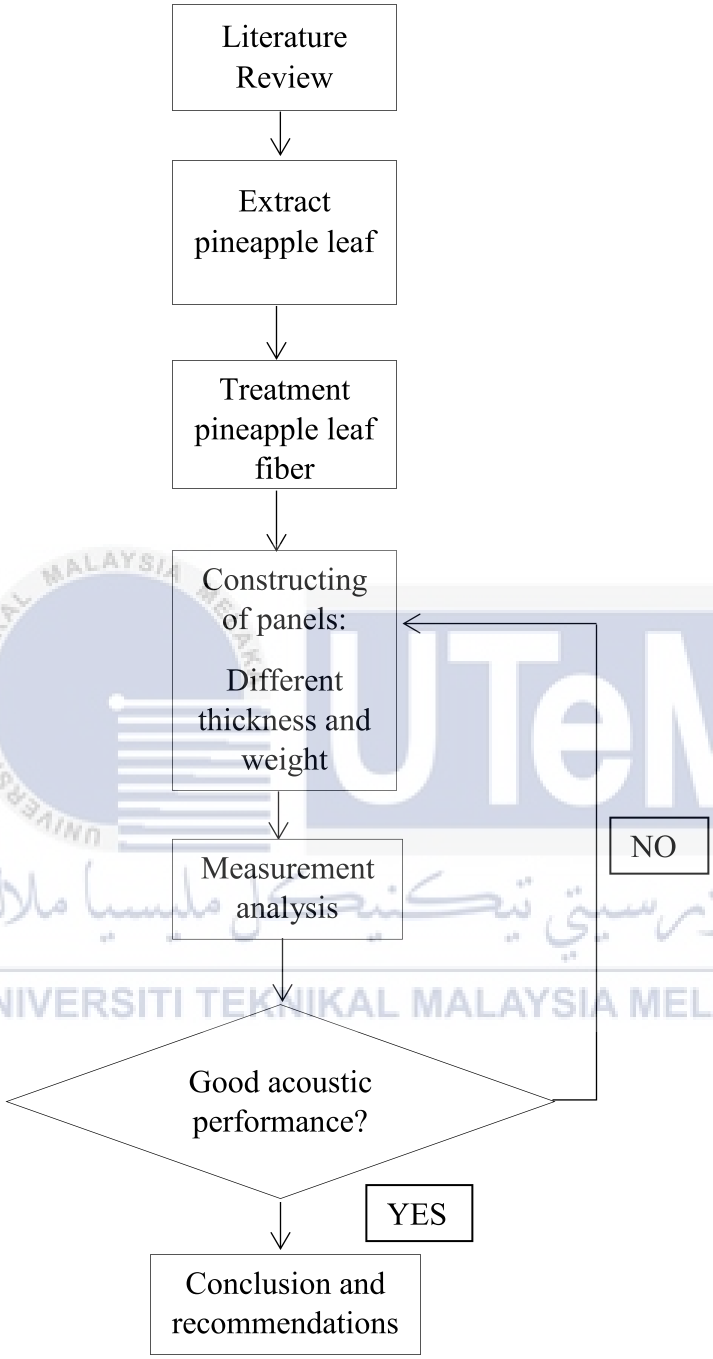



Figure 3.1: Flow chart of the methodology

Pineapple apple leaf in Figure 3.2 were harvested and collected at area of Muar, Johor, Malaysia. There are three types of pineapple cultivars are very popular which is Moris Gajah, Sarawak and Josapine. For this research, it use Moris Gajah and were collected around 100 leave. Table 1 shows the properties of properties of pineapple leaf.

Figure 3.2: Example of Pineapple Leaf used for this study

Table 3.1: Physical properties of Pineapple Leaf (Sapuan and Khalina, 2009)

| Property | Cultivar | | |
|---|---|---|---|
| | Moris Gajah | Josapine | Sarawak |
| Average no. of leaves | 50 | 65-70 | 65-70 |
| Length of leaves (mm) | 63 | 61 | 70 |
| Width of leaves (mm) | 61 | 46 | 65 |
| No. of fiber bundles per leaf | 90 | 80 | >100 |

### 3.3 Preparation of Fiber

#### 3.3.1 Extraction of fibers

In this process, fibers are extracted from pineapple leaf. The pineapple leaf contain large fiber bundles (100-460 µm) in the middle of the leaf and smaller technical fiber (30-80 µm) arranged longitudinally at the bottom of the leaf and the fiber surfaced is covered by waxy layer so in order to get the fiber, the waxy layer must be extract (Sapuan and Khalina, 2009). Figure 3.3 show the cross section of the pineapple leaf.

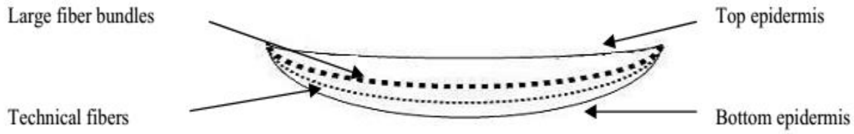



Figure 3.3: The cross section of the pineapple leaf (Sapuan and Khalina, 2009)

There are two methods that can be used to extract the pineapple leaf. First is by using conventional methods. The PALF is extracted on the bench by using scrapping tool as called "ketam" (Yusof et al., 2015). Figure 3.4(a) show the scrapping tool "ketam". The other method is by using novel technology which is using a machine. Conventional method consists of six steps compare to using machine only have two steps. Thus, by using conventional method need a more time to extract the pineapple leaf. So, for this research the collected PALF were extracted by using a machine "*Mesin Pemacah Daun Nenas*" as shown in Figure 3.4(b).

Figure 3.4(b): Scrapper Machine

Figure 3.4(a): Ketam (Yusof et al., 2015)



This machine consists of two blade or rollers, feed roller and leaf scratching roller (Banik et al., 2011). The pineapple leaf is fed through the feed roller and passed through the leaf scratching roller. During the leaf enter the roller the progression 'grind' working and for the first step the waxy layer remove. Second step is pulling off the leaf and the leaf grind for the second time to remove the residual wax layer at the leaf. Figure 3.5 shows the fiber after extract. According to Das et al., (2010) a pineapple leaf contains 2.5% - 3.5% of fiber from its weight.

Figure 3.5: Pineapple Leaf after extraction process

### 3.3.2 Fiber Treatment Process

According to Kannojiya et al., (2013), PALF contains chemical entities like Holocellulose (87.56%), Alpha-cellulose (78.11%), Hemicellulose (9.45%), and Lignin (4.78%). All the chemical constituents and also dirt and particle must be detached by using alkaline treatment. PALF was immersing in distilled water add with Natrium Hydroxide (NaOH) pellets as shown in the Appendix A1 for 1 hour in the beaker as shown in Appendix A2. Then, the fibers were washed by distilled water in order to neutralize remaining alkali. Lastly, the fiber was dried directly under the sun to remove the moisture. Last step is cut the fiber into short length between 30 mm to 33 mm using scissor. Figure 3.6 shows the pineapple leaf after the alkaline treatment process.

Figure 3.6: The pineapple leaf fiber after treatment process

## 3.4 Sample Preparation

The fiber was weighted by using electronic densimeter as shown in Figure 3.7(a) in order to determine the bulk density of the PALF. The weighted PALF then is immersed in the water and wait until all the air bubbles released from the PALF as shown in Figure 3.7(b) and basically the reading of the densimeter is stable when there is no more air bubbles released. Table 3.2 show the list PALF samples with the corresponding mass, volume, and bulk density. Every samples is measured by take some fibers and measured it by using densimeter and each samples is using different fibers. The density of the fibers is 1348.3 kg/m3. Table 3.3 shows the mass, volume, and bulk density of the aluminium web casing and it show that density of the aluminium web casing is 2599 kg/$m^3$.


Figure 3.7(a): Electronic Densimeter

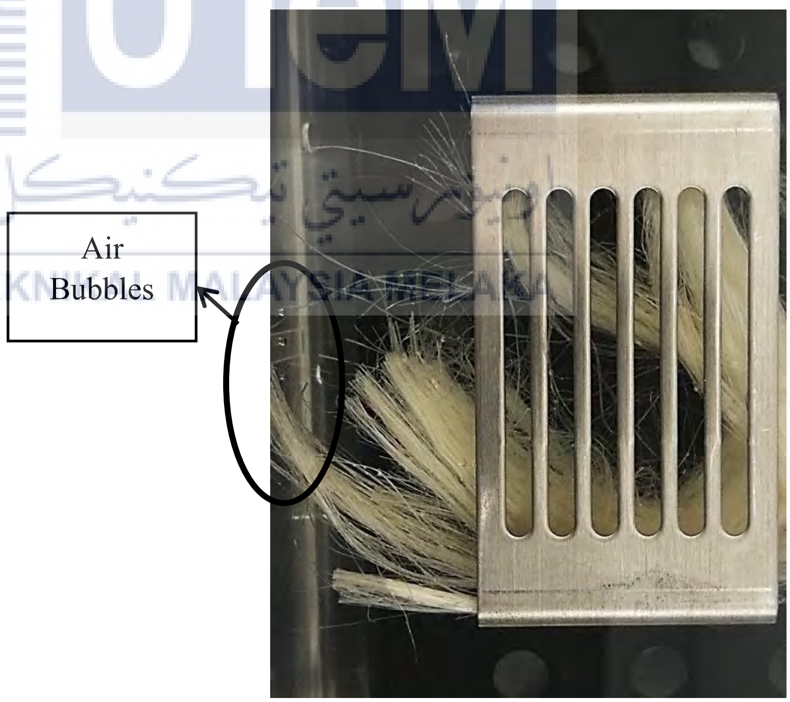



Figure 3.7(b): PALF immersed in the water

Table 3.2: List of PALF samples with the corresponding mass, volume, and bulk density

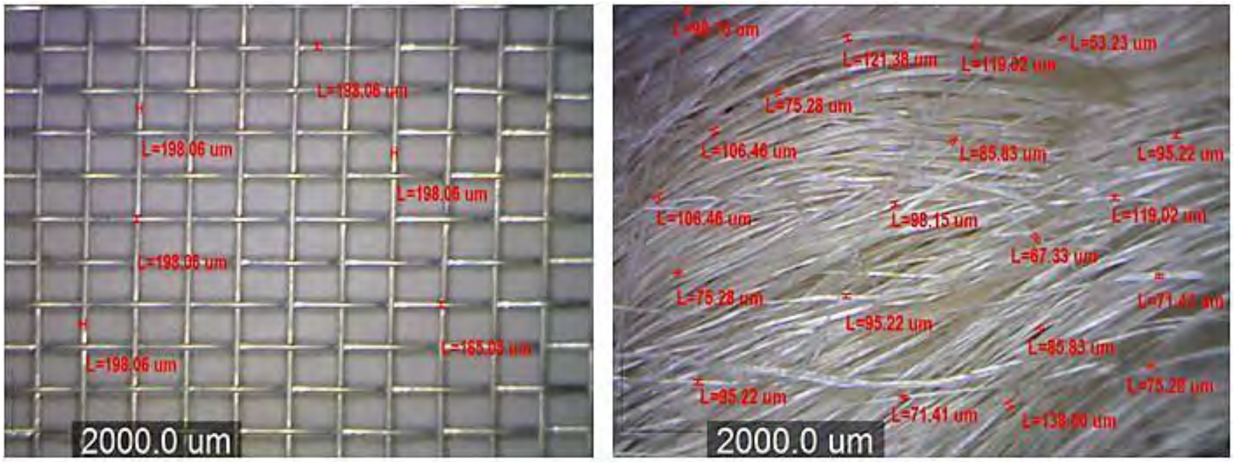
| **Sample no.** | **Mass of fibre (g)** | ***ρ* (g/cm3)** | **V (cm3)** | ***ρ* (kg/m3)** |
|---|---|---|---|---|
| 1 | 0.55 | 1.563 | 0.350 | 1563 |
| 2 | 0.54 | 1.327 | 0.406 | 1327 |
| 3 | 0.51 | 1.243 | 0.407 | 1243 |
| 4 | 0.57 | 1.297 | 0.439 | 1297 |
| 5 | 0.54 | 1.379 | 0.390 | 1379 |
| 6 | 0.51 | 1.534 | 0.331 | 1534 |
| 7 | 0.53 | 1.450 | 0.367 | 1450 |
| 8 | 0.52 | 1.294 | 0.405 | 1294 |
| 9 | 0.55 | 1.262 | 0.435 | 1262 |
| 10 | 0.24 | 1.134 | 0.211 | 1134 |
| | **Average** | 1.3483 | **Average** | 1348.3 |

Table 3.3: Mass, volume, and bulk density of the aluminium web casing

| | **Mass (g)** | ***ρ* (g/cm3)** | **V (cm3)** | ***ρ* (kg/m3)** |
|---|---|---|---|---|
| Aluminium-web casing | 0.12 | 2.599 | 0.048 | 2599 |



The aluminium web casing in Figure 3.8(a) and the diameter of the fibers in Figure 3.8(b) was determined by using the portable microscope. The magnification that use for the aluminium web casing is 21x and for the fibers is 31.5x. There are 25 of fibers is measured in order to determine its diameter. Every diameter fibers are measured from three different parts of the fibers. The average diameter for the pineapple leaf fiber is 172.92 µm. Figure 3.9 show a single fiber under the microscope and it diameter by using magnification 21x. The diameter of each fibers is shown in Appendix B1 and the other fiber under the portable microscope shown in Appendix B2.




(a) (b)

Figure 3.8: (a) Aluminium Web Casing (b) Raw PALF fibers under microscope


Figure 3.9: A single fiber under the microscope



For this research, the sample is fabricated by using different weight and different thickness. There are nine samples was prepared and the distribution of the sample tabulated at the Table 3.4.

Table 3.4: Distribution of the PALF samples

<table>
<tr><th>Mass of sample (g)</th><th>Thickness of casing (mm)</th><th>Bulk density $\rho = m/V$ (kg/m$^3$)</th><th>Diameter (mm)</th></tr>
<tr><td>1</td><td>10</td><td rowspan="6">116.92</td><td rowspan="9">33</td></tr>
<tr><td>2</td><td>20</td></tr>
<tr><td>3</td><td>30</td></tr>
<tr><td>4</td><td>40</td></tr>
<tr><td>5</td><td>50</td></tr>
<tr><td>6</td><td>60</td></tr>
<tr><td>1</td><td>20</td><td>58.46</td></tr>
<tr><td>2</td><td>30</td><td>77.95</td></tr>
<tr><td>3</td><td>20</td><td>175.38</td></tr>
</table>

For the base of the casing, the aluminium web casing was cut round shape with diameter 33 mm and for the wall of casing the aluminium was cut with length 105 mm according to the circumference of the shape. Then, the base and the wall is attached using glue. The PALF was compressed in the casing by using plunger according to the required thickness. After completed the required thickness, the top of the casing is close by round shape of the aluminium web casing. Figure 3.10 show the PALF fitted in the aluminium web casing. The sample is attached with cotton fabric at the front and the back. The purpose of this cotton fabric is to avoid from the fibers odor to the environment and also can improve the sound absorption performance. Figure 3.11 show the sample attached with cotton fabric at the front and the back of the casing. This is one of the parameter that been used in order to increase the performance of sound absorption of the PALF.


Figure 3.10: Test sample with different thickness and mass

Figure 3.11: Example of sample attached by fabric at the front and the back



### 3.5 Measurement of Absorption Coefficient

Figure 3.12 shows the general experimental setup for determining the sound absorption coefficient (α). Sound absorption coefficient measured by using impedance tube according to international standard ISO 10534-2. The experimental setup consists of two acoustic microphones (40AE), pre-amplifier (26CA), analyzer (RT Pro Photon v6.34) and the signal processing of the measurement data done by Matlab to acquire the graph (sound absorption vs frequency). The microphones is place at center of the impedance tube which is inserted into two thin metal hollow cylinder that perpendicularly to the impedance tube and the end of the impedance tube is loudspeaker and other end is sample of the material. The speaker is to produce wave of broadband noise and the sound wave flow through the tube raid directly to the panel. The sample holder holds the panel and to straighten the panel in normal position to the direction of sound wave propagates (Satyajeet and Rao, 2014). The other end of the impedance tube is removable cap (rigid), it is required because to reflect the sound wave.

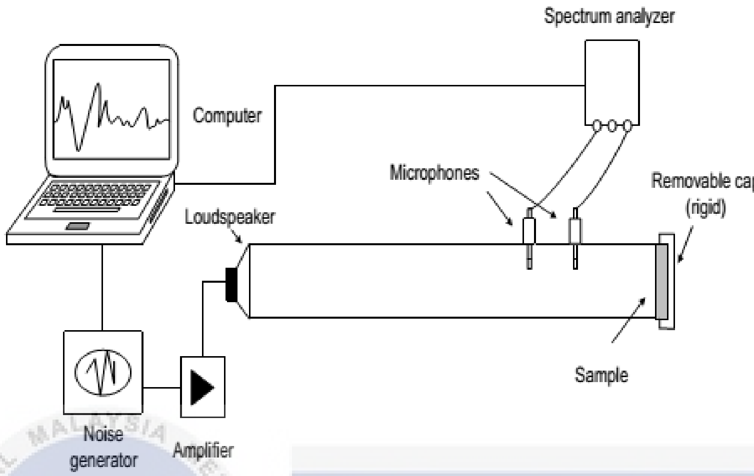
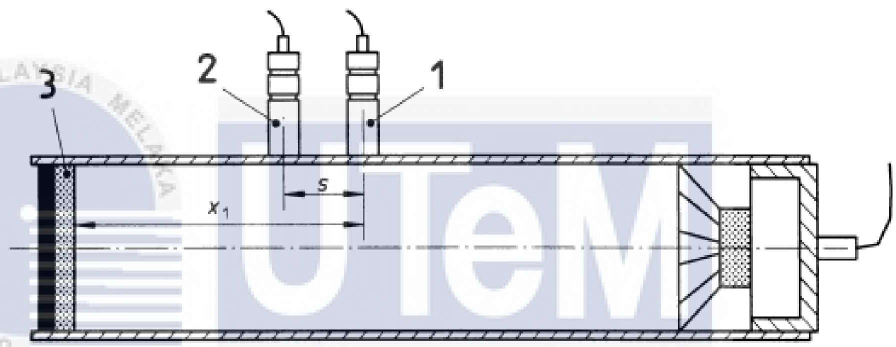



Figure 3.12: Experimental setup for sound absorption coefficient test (Putra et al., 2013)

The Pineapple Leaf Fiber (PALF) studied in this research is to measure the sound absorption coefficient (SAC) by using impedance tube. According to ISO 10534-2, the frequency range for this experiment is 500 Hz – 4500 Hz and 33 mm diameter of panels is suitable frequency for that frequency range. The panels should be fit in the sample holder but the panels should not be compressed and the panel should close-fitting to the impedance wall as shown in Figure 3.13.

Figure 3.13: Sample PALF fitted in the sample holder

The surface of the sample must be place normally to the tube axis. Before the experiment is been conducted, the calibrations of the microphones is performed in order to determine the acoustic centre of the microphone, and the corrections for attenuations in the impedance tube by using RT Pro Photon software.  Then, the loudspeaker must be operated at least 10 min in order to allow temperature to stabilize by using AUDACITY software. The microphone should be in positioned in such not disturb the plane wave generated and can measure the sound pressure levels inside the tube (Satyajeet and Rao, 2014). Figure 3.14 show the position of the microphone at the impedance tube. Lastly, by using Pro Photon software to run the impedance tube at least 1 minute. Then the signal processing of the data has done by using Matlab to acquire the graph.




**Key**

1 Microphone A

2 Microphone B

3 Test specimen



Figure 3.14: Position of microphone at the impedance tube

# CHAPTER 4

# RESULTS AND DISCUSSION

## 4.1 Introduction

Basically, the absorption occurs due to three factors which are viscous, thermal and structural losses caused by interaction between sound energy within the fibers in the sample. Viscous is the main part in order to damping the wave which is related to friction of sound wave with the fiber. The thermal losses take place when the friction between the fiber and sound wave occur. Lastly, the structural losses occur in poro-elastic materials where the fiber is deformed and the sound energy is transferred into the internal vibrations (Narkedamalli et al,. 2016). There are several methods in order to increase the performance of the sound absorption which is by using different thickness of samples, different density of samples, added a layer of fabric at the front and the back of the samples, and lastly introduce an air gap at the behind of the samples. The performance sound absorption of the samples is considered good when the sound absorption coefficient more than 0.5.

## 4.2 Effect of Thickness

Various studies that dealt with sound absorption in porous materials have concluded that low frequency sound absorption has direct relationship with thickness. Figure 4.1 shows the graph of the results effect of density with rigid backed on the sound absorption are coefficient. Figure 4.2 show the setup of the rigid backed in the sample holder of the impedance tube. The density uses for the samples is fixed which is 116.92 $kg/m^3$.

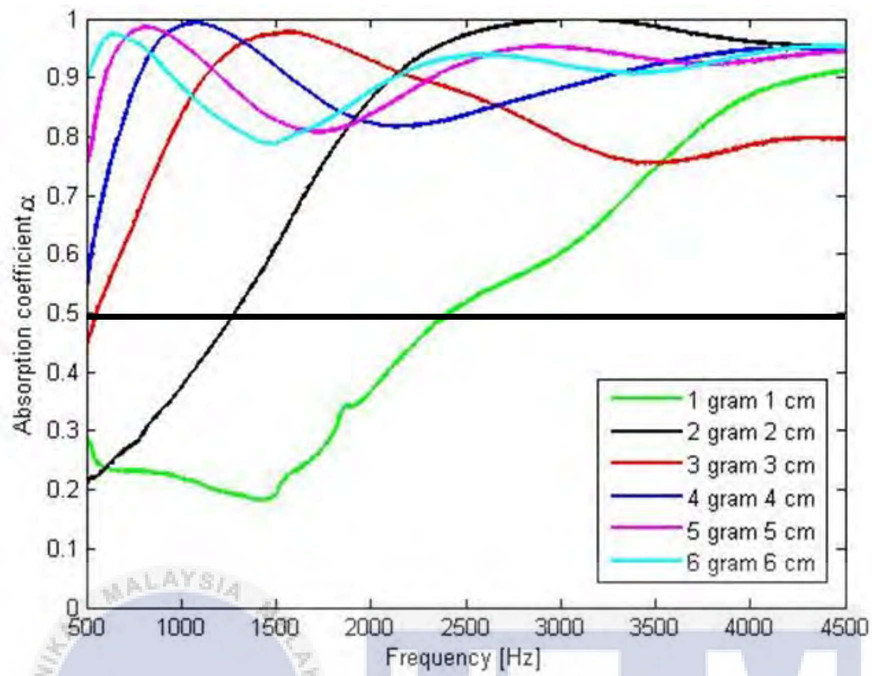



Figure 4.1: Sound absorption coefficient for different thickness with density 116 kg/m$^3$

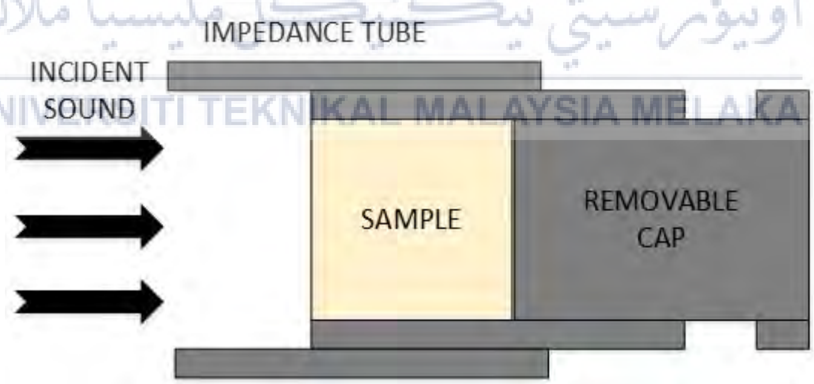
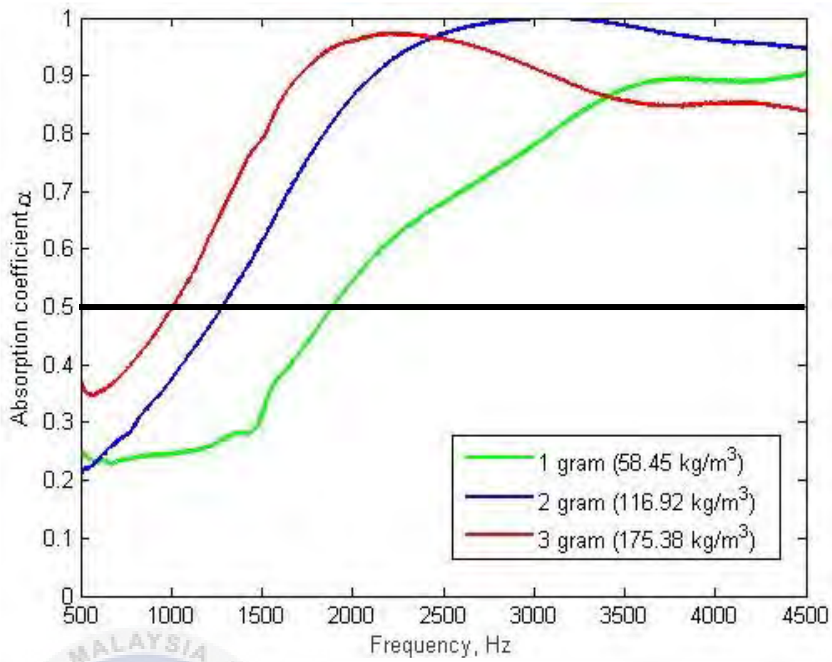



Figure 4.2: The setup for rigid backed behind the sample in the impedance tube

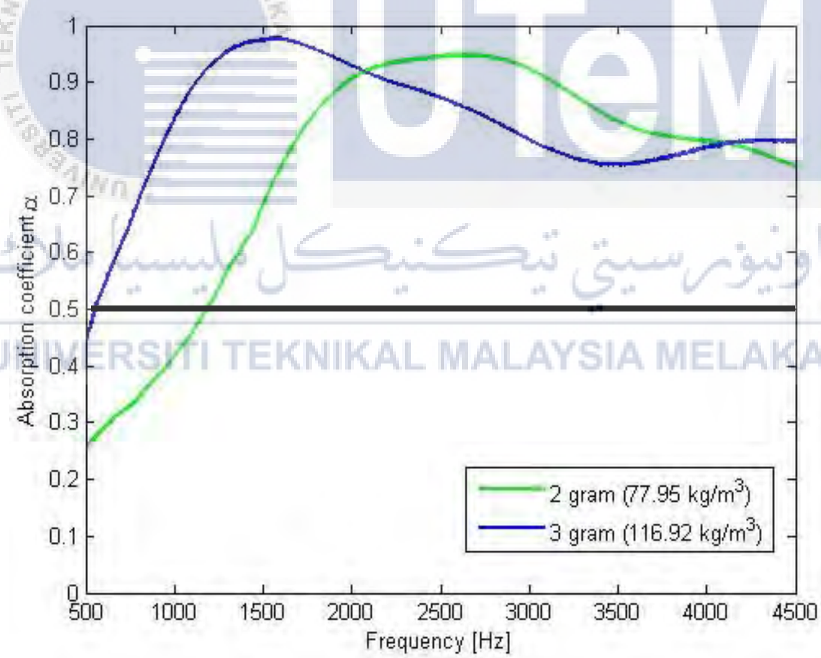
Generally, the sound absorption coefficient of pineapple leaf fiber was enhanced when the thickness of the sample enlarged. As the thickness of the samples increase, the sound energy have a long travel in the fiber so a lot amount of energy lost in the fiber before it reached at the wall in order to reflect the sound back. The porosity and flow resistivity for each samples is remain unchanged due to fixed density, the sound energy absorb and trapped due to the thicknesses increase for each samples. Essentially, more amounts of fibers were used to fabricate the samples with bigger thickness. From the Figure 4.1, the pattern of the graph at the lowest frequency (500Hz) increase as the thicknesses increase. The samples with 1 cm thickness show the lowest absorption coefficient at the lower frequencies which is only around 0.3 but the sample with 6 cm thickness show the highest absorption coefficient at the lower frequency which around 0.90 almost unity. The increasing of the thicknesses of the samples shifted the highest absorption coefficient to the lower frequency. For the sample 6 cm thickness, the peak absorption coefficient is 0.98 at the frequency 600 Hz, while for the sample 1 cm thickness, the absorption coefficient is 0.9 at the frequency 4500 Hz, so that the peak absorption coefficient is shifted to the lower frequency as the thickness increase. The samples that achieved sound absorption coefficient more than 0.5 is consider as the good absorption. The samples with 1 cm and 2 cm thickness achieved absorption coefficient 0.5 at the frequency more than 2400 Hz and 1350 Hz respectively, so that this samples is good absorbent at the higher frequency. The frequency range between 500 Hz to 2400 Hz, the sample with 1 cm thickness cannot absorb the sound energy and same goes to sample with 2 cm thickness which cannot absorb the sound at the frequency range between 500 Hz to 1350 Hz. The samples with thickness 4 cm, 5 cm, 6 cm can absorb sound energy completely at the frequency range 500 Hz to 4500 Hz due to the absorption coefficient achieved more than 0.5 and almost unity.

### 4.3 Effect of Density

Density of the material is another important factor that gives effect to the sound absorption. Figure 4.3 shows the results of sound absorption coefficient of pineapple leaf fiber with different density for the specific thickness. In this case, the samples with 2 cm and 3 cm thick are chosen in order to obtain the absorption coefficient. Density of the material is directly proportional to the mass of the sample, the more fiber per unit area will cause larger density of the material. This is also related to the porosity of the fiber, porosity mean air space between fibers which is the porosity is become packed when there is a lot amount of fiber in the sample. High amount of fiber in the small size of panel resulting the packed arrangement of fiber which is become high flow resistivity for the sound energy to pass through the fiber. Generally, the samples that with larger density absorbed more sound energy compare to smaller density due to the more surface frictional between the sound energy and the fibers of the sample resulting increasing of the sound absorption coefficient of the material. At density of 58.45 kg/m$^3$ (20 mm thick) the sound absorption coefficient more than 0.5 at frequency more than 1900 Hz while for the sample with density 175.38 kg/m$^3$ (20 mm thick) achieved 0.5 at frequency 1000 Hz which lower than the sample with density 58.45 kg/m$^3$. The increment of the density increases the absorption coefficient at the lower frequency range between 500 Hz to 1000 Hz. The peak absorption coefficient of the sample with density 58.45 kg/m$^3$ at the frequency range 3500 Hz to 4500 Hz and the peak is shifted to the lower frequency when the density (175.38 kg/m$^3$) is increase which is absorption coefficient achieved 0.98 at the frequency range 2000 Hz to 2500 Hz. Same goes to the sample with 30 mm thickness, the peak absorption coefficient for density 77.95 kg/m$^3$ is at the frequency range 2000 Hz to 3000 Hz and the resonance peak move to the lower frequency for density 116.92 kg/m$^3$ at the frequency range 1300 Hz to 1600 Hz. Increasing the thickness can be seen the increasing of the absorption coefficient below 3500 Hz but decreasing of the fiber density. Reducing the density of the fiber resulting decreasing of the flow resistivity. Using same amount of fiber but increasing the thickness of the sample make the sample have more open pores which is allow the sound energy penetrate easily into the fiber especially at the high frequency without any friction to convert the sound energy to heat. Basically, the increment of the density of the material contributes to increase of tortuosity and porosity which is resulting difficult path and the friction of the fiber between the sound energy is increase. Therefore more sound energy trapped and absorb in the fiber.




(a)




(b)



Figure 4.3: Measured sound absorption coefficient of PLF fibers with different thickness of samples (a) 20 mm thickness (b) 30 mm thickness

## 4.4 Effect of Fabric

Figure 4.4 shows the setup for fabric front and behind the sample in the impedance tube. Figure 4.5, 4.6 and 4.7 shows the sound absorption coefficient of PALF using same density 116 $kg/m^3$ added with fabric at the front and back of the samples.

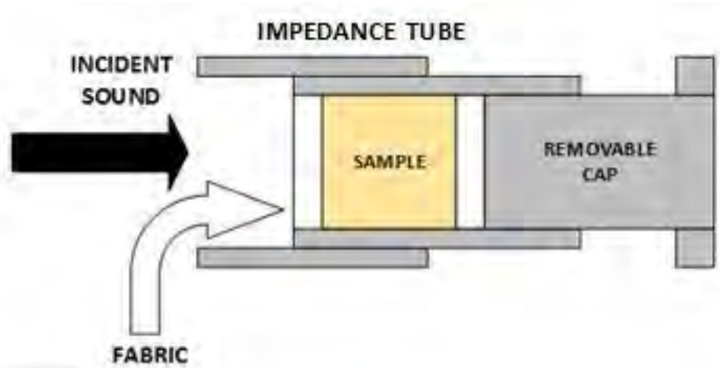



Figure 4.4: The setup for rigid backed added with fabric at the front and back of the sample in the impedance tube

From the graph, the sound absorption coefficient of PALF with nonwoven material at the front and the back of samples increase due to the decreasing of the porosity and increasing of the tortuosity path of the sample. Due to the natural twisting of the cotton fiber surface along the axial direction resulting the increase of the contact area between the fiber and sound energy. Therefore, more energy changed to vibration and frictional energy. Basically, the samples added with fabric are related to the thickness of the samples. By adding the fabric at the surface of the samples is same to the increasing of the samples thicknesses. The thicker samples resulting better absorption coefficient. Applying the fabric to the fiber is to keep the fiber from any fungus which is can affect the structure of the fiber. The fabric also can use as the decoration in order not to expose the casing and the fiber.

Applying the fabric at the front and the back of the samples is resulting increasing of the absorption coefficient at the lower frequency. The sample 1 cm thick (Figure 4.5) with fabric increase the peak absorption coefficient and achieved almost unity at the frequency range 4000 Hz to 4500 Hz while for the sample without fabric absorption coefficient is 0.9 at the frequency 4000 Hz to 4500 Hz which the peak absorption is increase and switch to the lower frequency. Sample with 2 cm thickness (Figure 4.6a) with fabric increase the sound absorption coefficient at the frequency 500 Hz from 0.2 to 0.3 compared to the sample without fabric. This is due to the fabric applying at the front of the sample, which the sound energy already starts to lose in the fabric. For the sample 3 cm thick (Figure 4.6b), the resonance peak shift to the lower frequency at frequency range 1200 Hz to 1500 Hz with applying the fabric. Absorption coefficient also increases at the high frequency region due to the increment of sample added with fabric. The sample with fabric achieves 0.9 at the frequency 4500 Hz compared to sample without fabric is 0.8 at the same frequency. Lastly, the sample with 4 cm thick as shown in Figure 4.7 only has a slightly different especially at the high frequency region between 2200 Hz to 4500 Hz. A lot of sound energy already lost in the fiber due to the thickness of the sample, therefore the fabric just gives a slight influence to the increasing of sound absorption coefficient for the thicker sample.

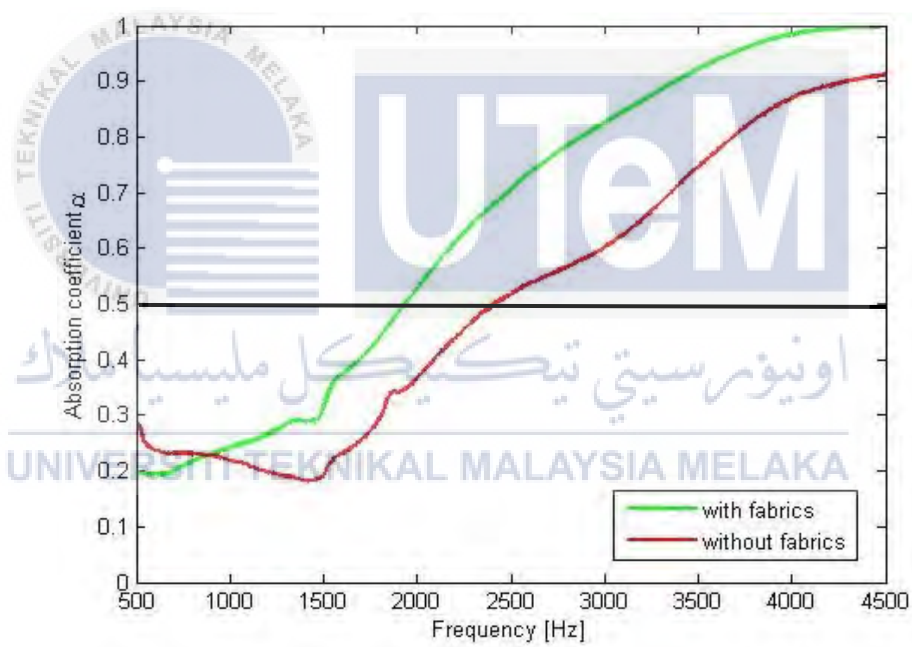
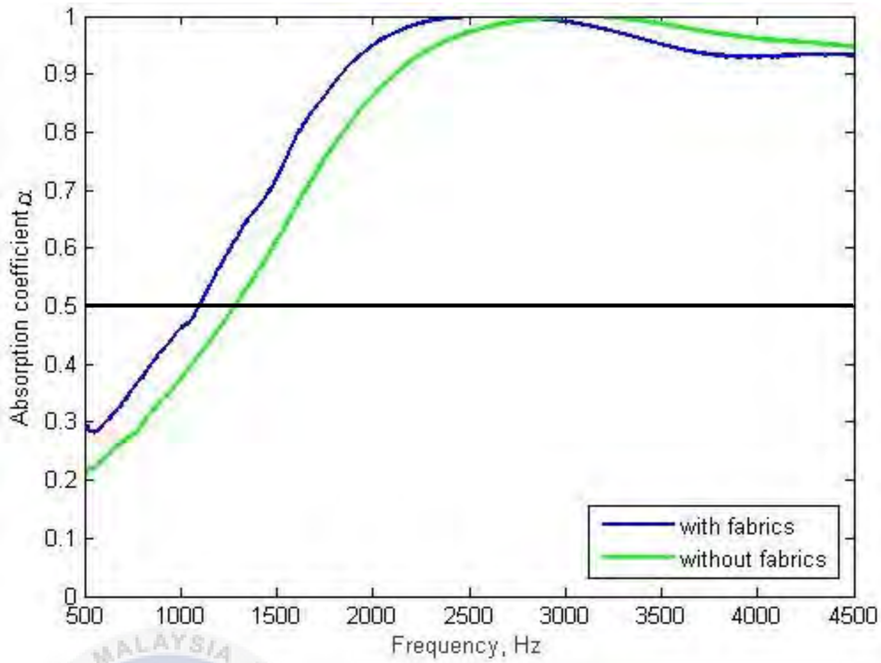
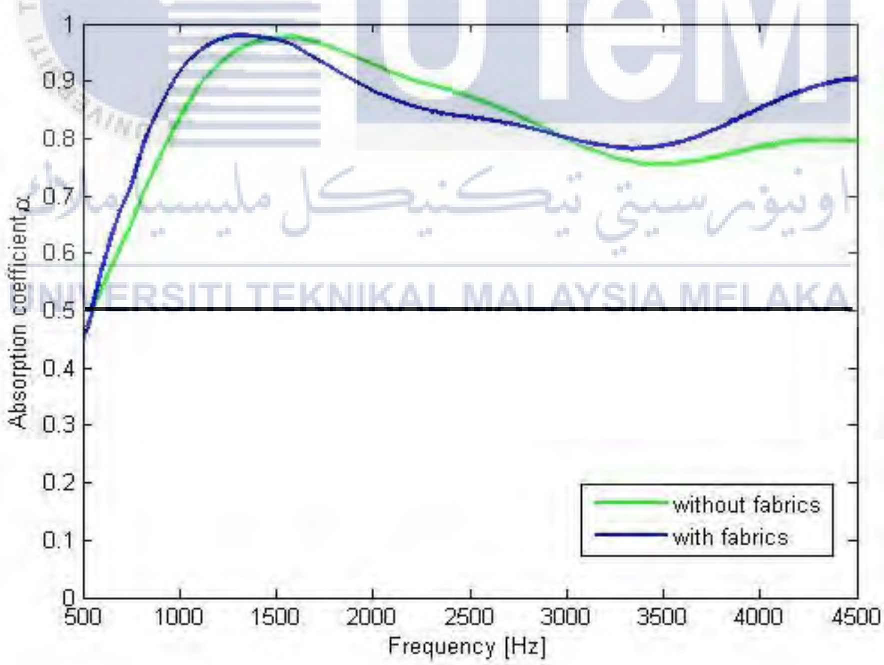





Figure 4.5: Measured sound absorption coefficient of PLF fibers with 1 cm thickness added with fabric at front and back of samples.




(a)




(b)

Figure 4.6: Measured sound absorption coefficient of PLF fibers with different thickness added with fabric at front and back of samples (a) 2 cm (b) 3 cm

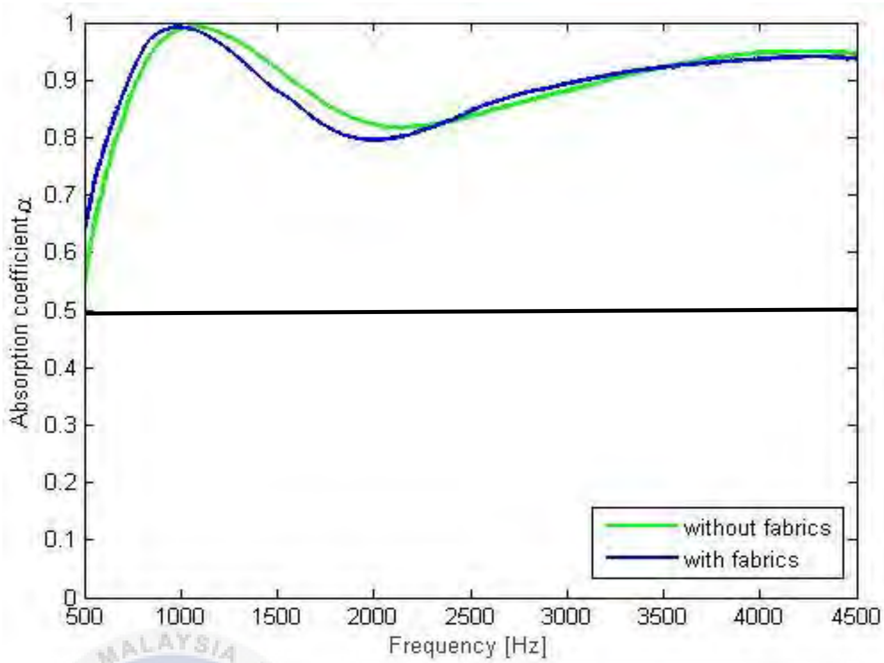



Figure 4.7: Measured sound absorption coefficient of PLF fibers with 4 cm thickness added with fabric at front and back of samples.

## 4.5 Effect of Air Gap

This research also study about the effect of air gap which is introduced at the behind of the sample. Figure 4.8 is the setup of the sample in the impedance tube.

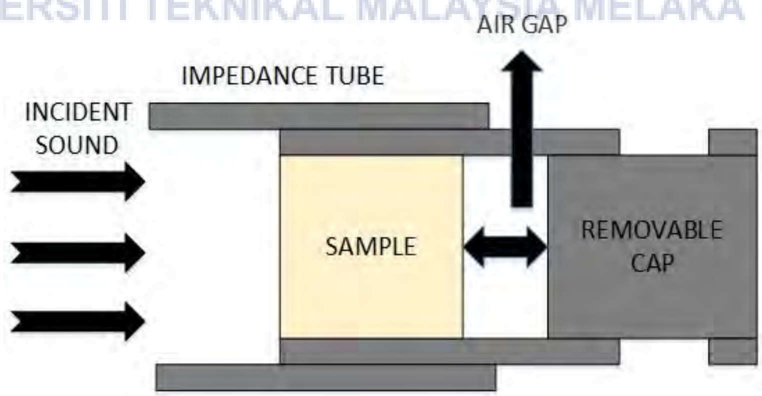
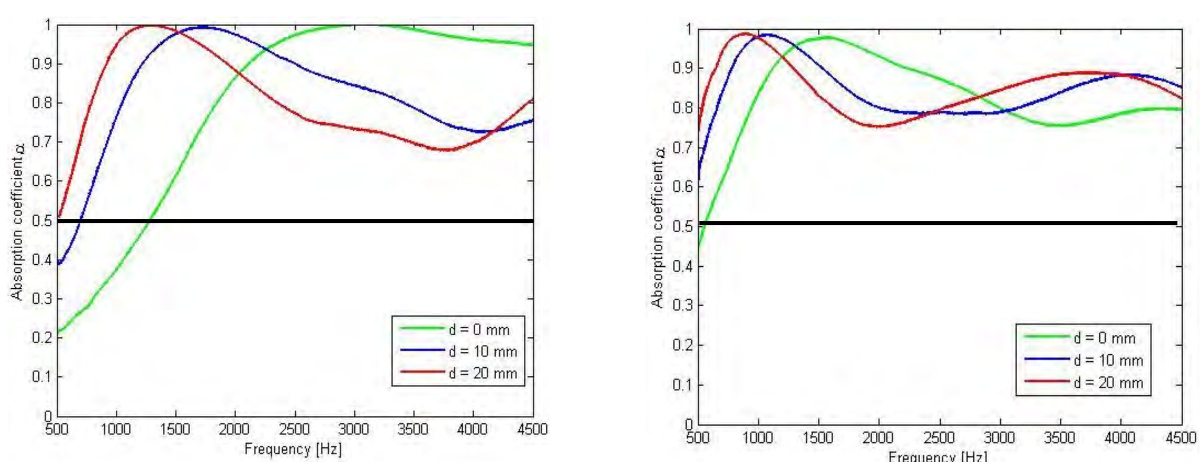



Figure 4.8: Illustrations of the air gap in the impedance tube

Figure 4.9 and 4.10 shows the sound absorption coefficient of the pineapple leaf fiber sample with different air gaps, d = 10 and 20 mm. Results show that the introduction of air gap between the sample and the wall enhances the sound absorption coefficient at the lower frequency due to the additional viscous dissipation from the air depth. The presence of the air space has allowed the pressure wave to dissipate the energy using another avenue. As shown in Figure 4.11 the sound energy circulates in the air gap without reflected back the sound energy to the environment. The sound energy passes through the fiber and directly to the wall and reflected back to the fiber then to the environment when there is no air gap behind the sample. The larger space between sample and the wall allows more air particles to vibrate and dissipate energy. From the graphs, it shows that the peak absorption coefficient for all samples is shifted to the lower frequency region due to the introduction of the air gap. For the sample with 20 mm thickness (Figure 4.9a), without air gap the sound absorption coefficient achieved 0.5 at the frequency 1350 Hz but with the introduction of air gap d=20 mm the sound absorption coefficient achieved 0.5 at frequency 500 Hz. Introduction of air gap improve the performance absorption of the sample with 20 mm thickness at the lowest frequency. For the sample with 60 mm thickness (Figure 4.10c), there is only slightly difference of the sound absorption coefficient with and without air gap especially at the middle frequency ranges 2300 Hz to 3000 Hz and there is no any change of sound absorption coefficient at the higher frequency range 3300 Hz to 4500 Hz. The sound energy already lost in the fiber due to the bigger thickness of the sample and high amount of fiber which is 6 gram.






(a) (b)

Figure 4.9: Measured sound absorption coefficient of PLF fibers with different air gaps (a) 20 mm thickness (b) 30 mm thickness

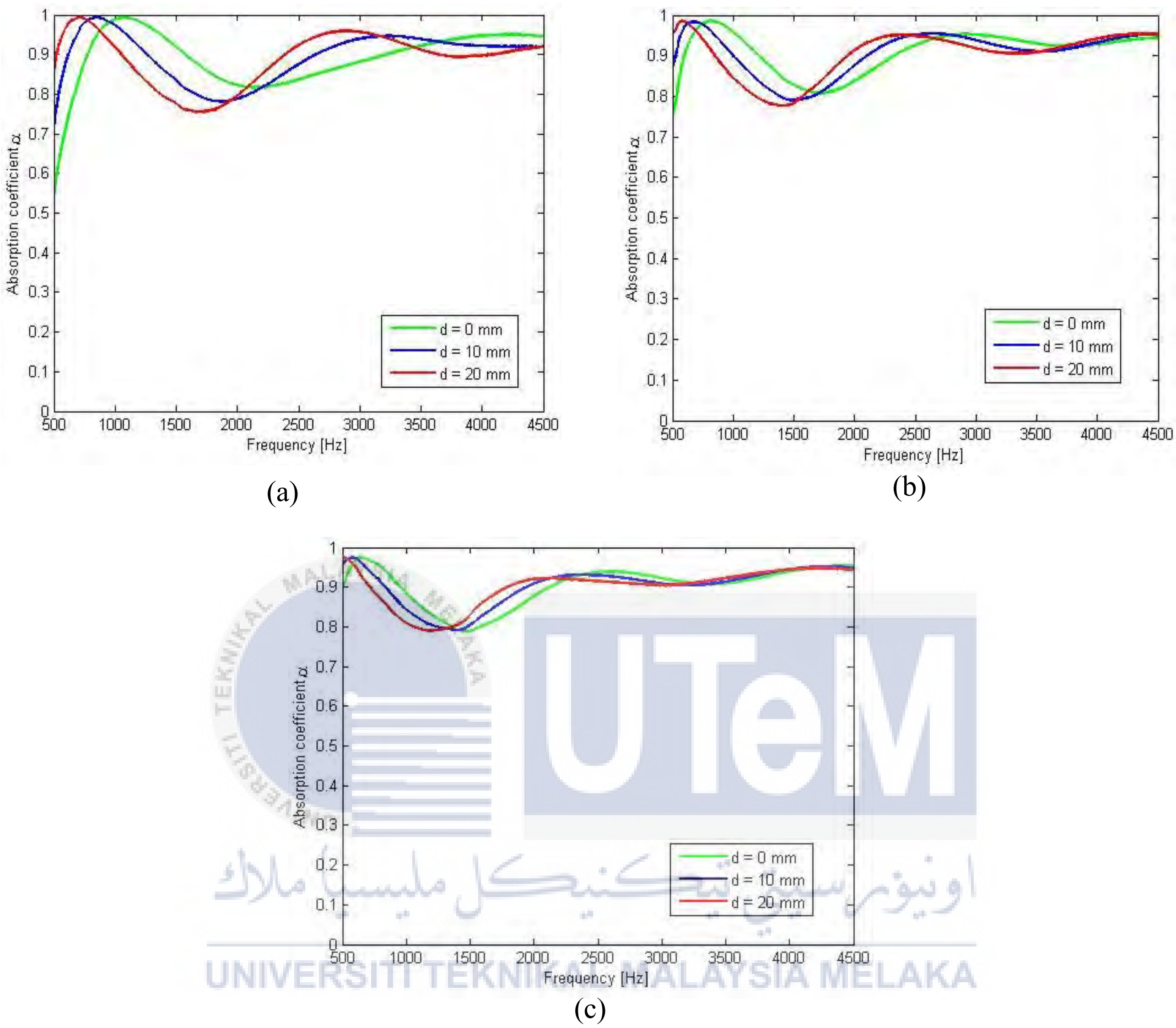



Figure 4.10: Measured sound absorption coefficient of PLF fibers with different air gaps (a) 40 mm thickness (b) 50 mm thickness (c) 60 mm thickness

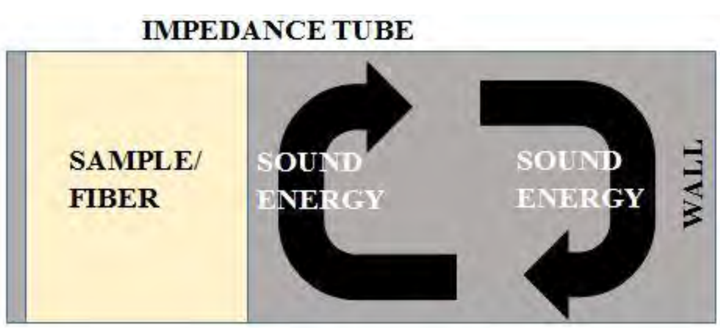
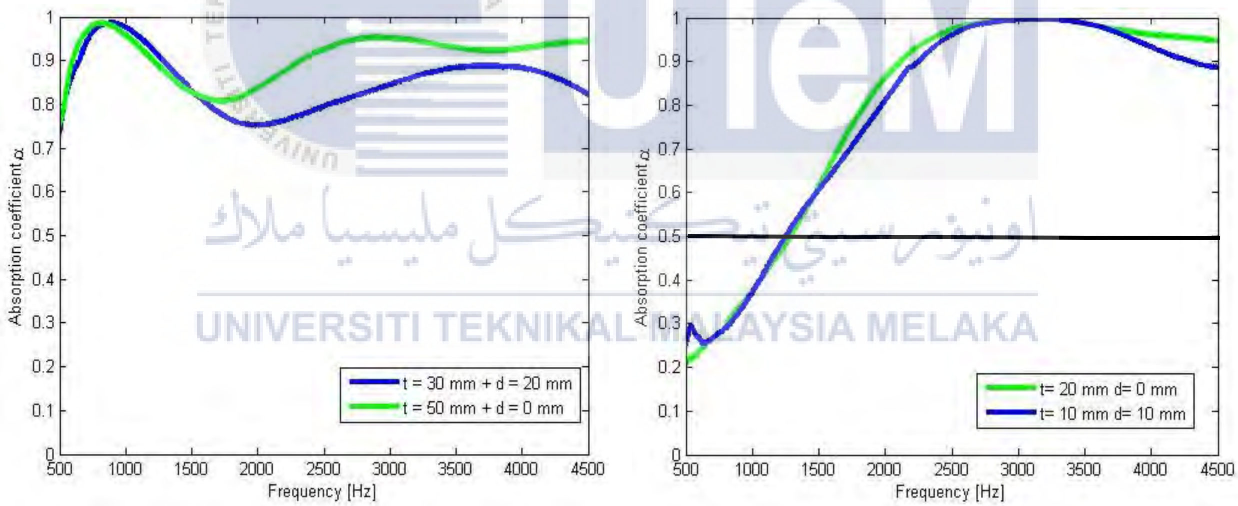


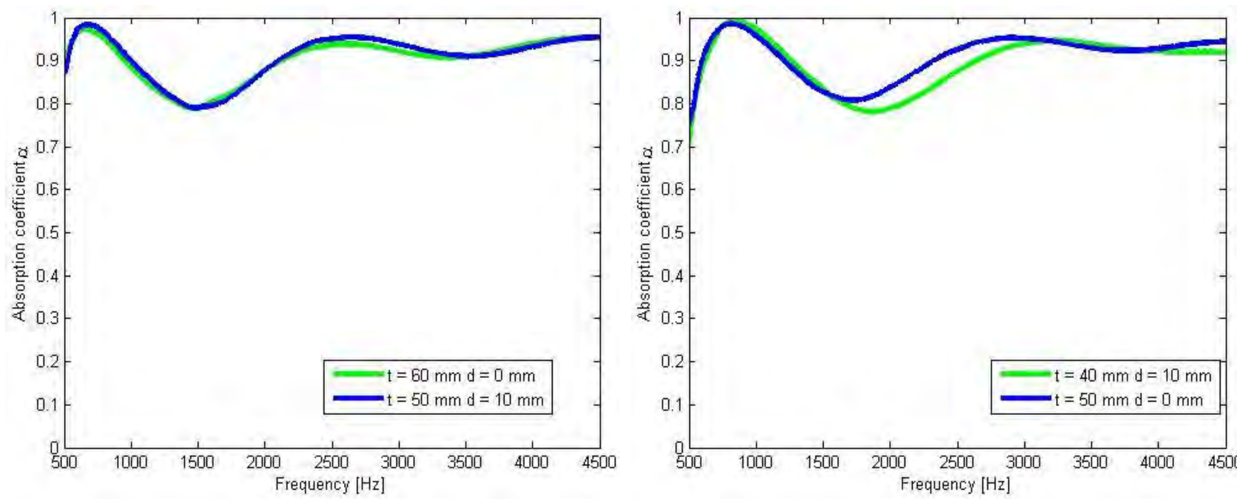

Figure 4.11: Sound energy circulates in the air gap

The purpose of introducing the air gap between the sample and the rigid wall is to increase the sound absorption coefficient at the lower frequency. Other than that, the introducing of air gap can save the fiber materials used. As shown in Figure 4.12(a), the performance of the sound absorption for the sample with thickness 30 mm and air gap thickness of 20 mm is demonstrates similar sound absorption performance as compared to the full thicker sample (rigid backing) which is there is no air gap behind the sample of 50 mm thickness at the frequency range 500 Hz to 1500 Hz. As shown in Figure 4.13(a), the performance of the sound absorption for the sample with thickness 60 mm (full thicker) is same with the performance for the sample with thickness 50 mm and 10 mm air gap from frequency 500 Hz to 4500 Hz. Instead using of the full thicker (rigid backing) sample, the good performance can be achieved by introducing the air gap between the sample and the rigid wall. This is can be save a lot amount of the fiber use to fabricate the panel and can produce the light panel.




(a) (b)

Figure 4.12: Comparison of sound absorption coefficient between samples with thickness (a) t = 30 mm + d = 20 mm and t = 50 mm full thicker (b) t = 10 mm + d = 10 mm and t = 20 mm full thicker at the same PALF density of 116.92 kg/m$^3$




(a) (b)

Figure 4.13: Comparison of sound absorption coefficient between samples with thickness (a) t = 50 mm + d = 10 mm and t = 60 mm full thicker (b) t = 40 mm + d = 10 mm and t = 50 mm full thicker at the same PALF density of 116.92 kg/m$^3$

## 4.6 Summary

As the conclusion, the increment of the sample thickness enhances the performance of the sound absorption at lower frequency. This is due to the long travel of sound energy in the sample, more frictions occur between sound energy and the fibers. From the results, it shows that the samples with thickness 30 mm to 50 mm of sound absorption coefficient in average 0.98 at the frequency range 1000 Hz. The density of the fiber also gives effect to sound absorption coefficient by increasing the flow resistivity of the samples. The more amounts of fibers in the sample, the higher the resistivity of the samples due to packed arrangement of fibers in the sample. Applying of the fabric to the sample can increase the performance of sound absorption which is the friction occur between sound energy and the fiber of the fabric. The performance of the sound absorption coefficient is unchanged for the sample with 40 mm thicknesses. This is because the sound energy already loss in the fiber due to the bigger thickness.

# CHAPTER 5

# CONCLUSION AND RECOMMENDATIONS

## 5.1 CONCLUSION

Samples of sound absorber from pineapple leaf fibers that extracted from pineapple leaf are fabricated with different size and mass. The samples have been tested for their sound absorption performance by using impedance tube according to standard ISO 10534-2 has been reported. The experimental results show that this natural fiber can be utilized as a potential alternative acoustic material. The performance of sound absorption considered is good absorption when the sound absorption coefficient achieved more than 0.5. With thickness of 30 mm and 3 grams of fiber weight, the sound absorption coefficient is more than 0.5 above 550 Hz and can reach peak absorption 0.98 at the 1500 Hz. The performance of sound absorption enhance with the increment of thickness of the sample by shifted the peak frequency to the lower frequency. For the samples with the thickness 40 mm, 50 mm, and 60 mm, the sound absorption coefficient achieved more than 0.5 at the 500 Hz and the peak frequency is almost unity on average frequency range 500 Hz to 1000 Hz. By introducing the air gap between the sample and the rigid wall, the peak frequency is shifted to the lower frequency. Besides, applying the fabric at the front and back of the samples also enhances the performances of the absorption, but the performances are unchanged for the sample with 40 mm thickness at the higher frequency. This is because the sound energy already lost in the fiber due to the bigger thickness. It has also been discussed that care has to be taken when designing the density of the absorber, as too dense fibers can deteriorate the sound absorption performance.

## 5.2 RECOMMENDATIONS

In order to fully confirm the robustness of pineapple leaf fibers in practice, additional environmental tests are required, for examples the fire retardant, fungal growth, humidity and thermal conductivity tests which are of interest in the extension of this current work. Besides, comparing the experimental work with some already existing theoretical models also can be done for examples Allard-Johnson model, Miki model and Delany-Bazley model. If the experiment conducted correctly and normally the results (graph) from the experimental work is almost same with theoretical modelling.

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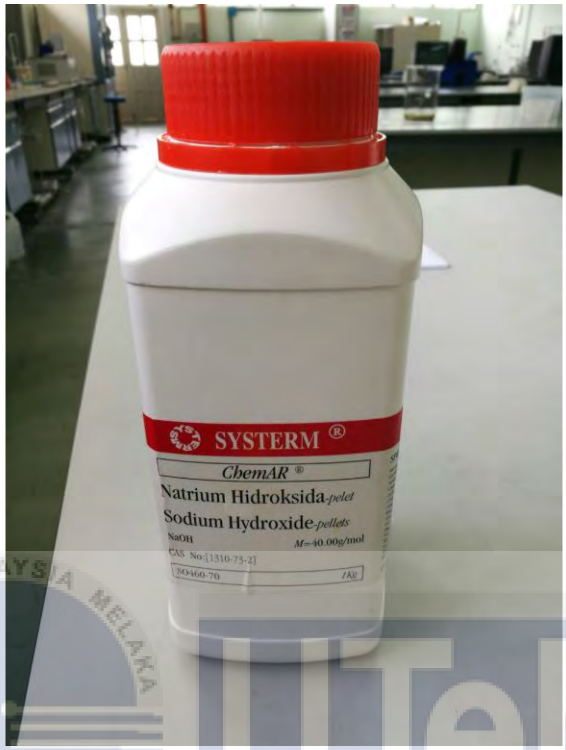
## APPENDIX A1




## APPENDIX A2

**APPENDIX B1**

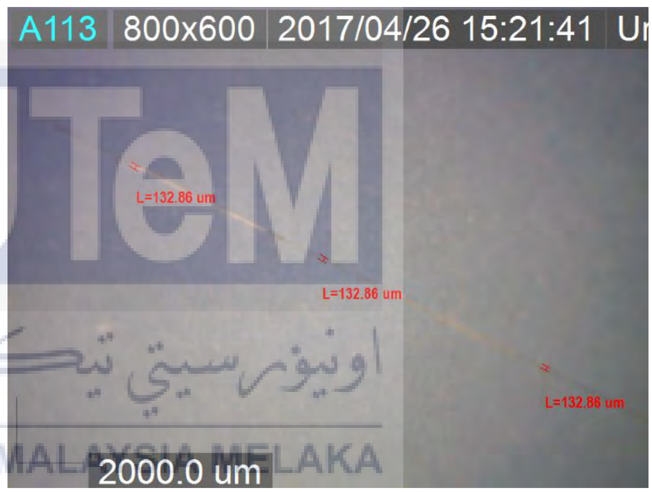
| Sample no. | Diameter of fiber (μm) | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | Average |
| 1 | 239.52 | 210.07 | 239.52 | 229.7033 |
| 2 | 216.28 | 281.84 | 253.83 | 250.6500 |
| 3 | 148.54 | 151.48 | 180.71 | 160.2433 |
| 4 | 132.86 | 132.86 | 132.86 | 132.8600 |
| 5 | 210.07 | 237.67 | 180.71 | 209.4833 |
| 6 | 180.71 | 132.86 | 107.11 | 140.2267 |
| 7 | 180.71 | 180.71 | 151.48 | 170.9667 |
| 8 | 148.54 | 148.54 | 148.54 | 148.5400 |
| 9 | 132.86 | 132.86 | 132.86 | 132.8600 |
| 10 | 187.89 | 151.48 | 122.49 | 153.9533 |
| 11 | 190.23 | 190.23 | 190.23 | 190.2300 |
| 12 | 118.83 | 89.12 | 118.83 | 108.9267 |
| 13 | 122.49 | 122.49 | 180.71 | 141.8967 |
| 14 | 173.23 | 214.23 | 173.23 | 186.8967 |
| 15 | 190.23 | 190.23 | 232.03 | 204.1633 |
| 16 | 159.98 | 159.98 | 187.89 | 169.2833 |
| 17 | 187.89 | 187.89 | 216.28 | 197.3533 |
| 18 | 173.23 | 173.23 | 173.23 | 173.2300 |
| 19 | 159.98 | 159.98 | 187.89 | 169.2833 |
| 20 | 159.98 | 159.98 | 159.98 | 159.9800 |
| 21 | 190.23 | 232.03 | 210.07 | 210.7767 |
| 22 | 173.23 | 173.23 | 148.54 | 165.0000 |
| 23 | 210.07 | 168.06 | 126.04 | 168.0567 |
| 24 | 190.23 | 148.54 | 148.54 | 162.4367 |
| 25 | 199.29 | 159.98 | 199.29 | 186.1867 |
| | | | **Average** | 172.9275 |

**APPENDIX A2**


A110
800x600
2017/04/26 15:16:05
L=239.52 um
L=210.07 um
L=239.52 um
2000.0 um


A111
800x600
2017/04/26 15:18:44
L=216.28 um
L=281.84 um
L=253.83 um
2000.0 um


A112
800x600
2017/04/26 15:20:53
L=180.71 um
L=151.48 um
L=148.54 um
2000.0 um


A113
800x600
2017/04/26 15:21:41
L=132.86 um
L=132.86 um
L=132.86 um
2000.0 um




A114
800x600
2017/04/26 15:21:55
L=210.07 um
L=237.67 um
L=180.71 um
2000.0 um


A115
800x600
2017/04/26 15:22:14
L=180.71 um
L=132.86 um
L=107.11 um
2000.0 um

Gantt Chart for Final Year Project (PSM1)

| NO | TASK | WEEKS | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 1 | Preparation of Literature Study | | | | | | | | MID-TERM BREAK | | | | | | | | | | | |
| 2 | Chapter 1: Introduction | | | | | | | | | | | | | | | | | | | |
| 3 | Chapter 2: Literature Review | | | | | | | | | | | | | | | | | | | |
| 4 | Researching for Methodology | | | | | | | | | | | | | | | | | | | |
| 5 | Presentation Project Proposal | | | | | | | | | | | | | | | | | | | |
| 6 | Chapter 3: Methodology | | | | | | | | | | | | | | | | | | | |
| 7 | Submission Progress Report 1 | | | | | | | | | | | | | | | | | | | |
| 8 | Chapter 4: Preliminary Result | | | | | | | | | | | | | | | | | | | |
| 9 | Report Writing | | | | | | | | | | | | | | | | | | | |
| 10 | Draft Report Submission | | | | | | | | | | | | | | | | | | | |
| 11 | Report Submission | | | | | | | | | | | | | | | | | | | |
| 12 | PSM 1 Seminar | | | | | | | | | | | | | | | | | | | |

Gantt Chart for Final Year Project (PSM-2)

| No | Task | Week | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 1 | Chapter 3: Methodology | | | | | | | | | | | | | | | |
| 2 | Sample Preparation | | | | | | | | Mid Term Break | | | | | | | |
| 3 | Experiment and Data Validation | | | | | | | | | | | | | | | |
| 4 | Chapter 4: Results and Discussion | | | | | | | | | | | | | | | |
| 5 | Chapter 5: Conclusion and Recommendations | | | | | | | | | | | | | | | |
| 6 | Report Writing | | | | | | | | | | | | | | | |
| 7 | Correction of report PSM 1 | | | | | | | | | | | | | | | |
| 8 | Final Report Submission | | | | | | | | | | | | | | | |