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ACOUSTIC ABSORPTION PROPERTIES OF FIVE KINDS OF MYANMAR WOOD

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Abstract

The acoustic absorption property is commonly used to characterize and rank of the materials to reduce noise. The purpose of this research is to study the sound absorption coefficient of five kinds of Myanmar wood such as Pyinkado (Xylia xylocarpa Taub.), Teak (Tectona grandis), Kanyin (Dipterocarpus), Rubber (Hevea brasiliensis) and Pine (Pinus sp. L.). The experimental investigation of sound absorption coefficient was conducted based on one microphone impedance tube method for the working frequency ranging from 100 Hz to 2600 Hz. The morphology of test wood samples is characterized by optical microscope. The results show that the sound absorption coefficient of five kinds of wood samples depend on the number of vessel as well as vessel diameter and teak wood has better sound absorption coefficient in comparison with others.

Keywords: Myanmar wood, one microphone impedance tube, sound absorption coefficient

Introduction

Pollution affects the ecosystem of the planet causes discomfort to almost every living organism on it. Typically, there are several types of pollution, which are: air pollution, water pollution, noise pollution, and land pollution which come from different sources and have different consequences. Among other pollutions, noise pollution is also dangerous for human and nature; it causes damaging the ability to hear, damaging to liver, brain and heart, leading to emotional and behavioral stress. Noise pollution is coming from many sources: household sources, social events, commercial and industrial activities, and transportations.

Moreover, use of loudspeakers in the religious affairs, festivals and charity has become a nuisance in our city. Therefore, controlling sound source and using sound-absorbing materials are also the most effective and practical way to reduce unwanted noise in the sound environment like public buildings, offices, shopping centers or dining spaces (Shen, M. H. & Lai, R. P., 2011). Wood is well known for its acoustic quality in various musical instruments and is also suited as sound absorber or sound diffuser (Smardzewski, J., & Batko, W., 2014).

The most important acoustic parameter for reducing unwanted noise is sound absorption coefficient. The term “noise” is unwanted sound judged to be unpleasant, loud or disruptive to hear. There are two basic methods of measuring sound absorption. The first method comprises the use of a reverberation room giving results valid for random incidence in a diffuse sound field and is suitable for large objects, furniture, panels, etc. The second method comprises the use of an impedance tube, giving results valid for normal incidence in a plane wave sound field, which is suitable for testing small samples (Nandanwar, A., 2017). In this study, impedance tube is constructed according to ISO 10534:1 and 10534:2 regulations and it was used in measuring sound absorption coefficient of wood.

Although there is a plenty of sound absorption information for commercial construction materials, there is a lack of data related to acoustic properties of wood and wood based panel

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products. Negro F. (Negro, F., Cremonini, C., Properzi M., & Zanuttini R., 2010) studied sound absorption coefficient of perforated plywood by the impedance tube (Kundt's tube) method. He found that the absorption properties of perforated plywood depending on the cavity thickness at their back. Jayamani E. et al. (Jayamani, E., et al., 2013) presented sound absorption coefficients of four types of Malaysian wood with two microphone impedance tube method. They found that the sound absorption coefficient depends on the frequency of the sound which strikes material and density of materials.

The current research focuses on the sound absorption properties of Myanmar wood samples commonly used in the building construction and furniture. The test wood materials were prepared in circular shape by using CNC machine. Then, one microphone impedance tube was designed and constructed by one microphone impedance tube method. In this research, Myanmar wood samples are investigated for sound absorption coefficient measurement at the frequency ranging from 100 Hz to 2600 Hz.

Preparation of Wood Sample for Sound Absorption Measurement

The Myanmar wood samples (such as Pyinkado, Teak, Kanyin, Rubber and Pine) were used to investigate the sound absorption coefficient using one microphone impedance tube method. These test materials were prepared according to the sample holder of one microphone impedance tube method. These test materials were 1.5 cm thick and cut it into circular shape with diameter of 8.8 cm using a computer numerical control (CNC) milling cutter machine as shown in Figure 1. It was ensured that the sample was fit slung into the impedance tube which is not loosely in order to avoid the space between its edge and the sample holder.

(a) (b)

Figure 1 (a) Preparation of wood material by using CNC milling cutting machine
(b) Wood materials (1) Pyinkado, (2) Teak, (3) Kanyin, (4) Rubber and (5) Pine

Impedance Tube Theory

The acoustic impedance tube is a common experimental apparatus that is used to measure the acoustic absorption coefficient and acoustic impedance of a porous sound absorbing material according to the theory of the standing wave. The standing wave is generated by the superposition of the incident and reflected sound waves in the impedance tube. Acoustic impedance tube employs a sound source and specially placed microphones to measure the acoustic properties of a material that is placed inside of the tube. This standard describes two methods: (a) standing wave ratio method (with one moving microphone) and (b) transfer function method (with two microphones).

The impedance tube method was developed with ISO 10534-2, ASTM E-1050 as reference which describes the two-microphone method or the transfer function method for measuring the sound absorption coefficient of acoustical materials. This test method can be applied to measure sound absorption coefficient of absorptive materials at normal incidence. Normal incidence sound absorption coefficients are useful in basic research and product development of sound absorptive materials like polyurethane foam. This method is quite useful in situations where the material being tested in placed in cavities just like the present case of impedance tube.

This study is a technique to use one fixed microphone instead of two microphones, which is similar to transfer function method. The benefit of using one fixed microphone is that there is no calibration required since the same microphone is being used through the entire test. This method involves the use of impedance tube, data acquisition board, the microphone and the sound source speaker.

Standing Wave Ratio Method

One of the earliest forms of acoustic impedance tube is used to measure properties for the calculation of acoustic properties of materials by measuring the standing wave ratio (SWR). A typical SWR tube is depicted in Figure 2. The SWR tube has a speaker on one end of the tube with a test specimen on the other end. The speaker produces a single frequency sinusoidal tone, which forms plane waves as it travels down the tube. This is the incident pressure wave that is designated in Figure 2 as P_i. In this Figure, the arrow points in the direction that the wave travels. The sound waves travels through the specimen causing some of the sound to be absorbed and some to be reflected. This is the reflective pressure wave that is designated in Figure 2 as P_r, where the arrow points the direction of the speaker. A standing wave is formed by the combination of the traveling incident and reflected waves. This wave is denoted in Figure 2 as the line between the two maximum dotted lines. The pressure inside the tube is measured using a microphone probe by moving the microphone probe further inside the tube in an attempt to discover the minima and maxima of the standing wave. Once the maximum and minimum pressures are found, their corresponding values were recorded so that the standing wave ratio could be calculated.

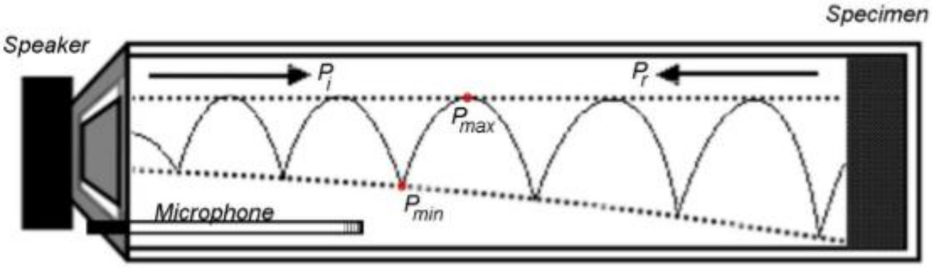


Figure 2 SWR Impedance Tube with a standing wave created by the incident and reflective Pressure waves

$$SWR = \frac{P_{max}}{P_{min}} \qquad \cdots\cdots\cdots (1)$$

P_i and P_r (depicted in Figure 2) are the pressures of the incident and reflective waves, respectively. Although the incident and reflective pressure waves cannot be directly measured by the microphone, the sum and difference between them can be. This is done by measuring the maximum and minimum points on the standing wave. Then, using this ratio, the acoustic reflection coefficient can be calculated. The underlying process is described in the equation

$$\mathrm{R} = \frac{[\mathrm{SWR}-1]}{[\mathrm{SWR}+1]} \qquad \cdots\cdots\cdots (2)$$

Using the reflection coefficient, the absorption coefficient α can be calculated as

$$\propto = 1 - |R|^2 \qquad \cdots\cdots\cdots (3)$$

The absorption coefficient is then used to calculate the specific acoustic impedance, z as

$$\mathrm{z} = \frac{(1+\mathrm{R})}{(1-\mathrm{R})} \qquad \cdots\cdots\cdots (4)$$

Transfer Function Method

Like the standing wave ratio method, the transfer function method consists of a tube with a speaker at one end and a test sample at the other. Instead of using a microphone probe, two microphones are located along the tube at known distances between each other and the surface of the specimen. A specimen of material is placed in a sample holder and mounted at the other end of the speaker. The transfer function H_{12} can be measured between two microphones. From these transfer function H_{12}, the reflection coefficient of sound pressure of the material (R) is defined as

$$R = \frac{\mathrm{e}^{-\mathrm{jkx}_2} - \mathrm{H}_{12}\mathrm{e}^{-\mathrm{jkx}_1}}{\mathrm{H}_{12}\mathrm{e}^{-\mathrm{jkx}_1} - \mathrm{e}^{-\mathrm{jkx}_2}} \qquad \cdots\cdots\cdots (5)$$

where x_1 is the distance from the specimen face to microphone 1, x_2 is the distance from the specimen face to microphone 2.

From the reflection coefficient, the specific impedance ratio can be calculated.

$$\frac{\mathrm{Z}}{\rho\mathrm{c}} = \frac{1+\mathrm{R}}{1-\mathrm{R}} \qquad \cdots\cdots\cdots (6)$$

The absorption coefficient (α) of the material is defined as follow

$$\alpha = 1 - |\mathrm{R}|^2 \qquad \cdots\cdots\cdots (7)$$

One Microphone Impedance Tube Method

The ISO 10534-2 standards also describe a technique to use one microphone instead of two microphones. This method can also be said to be equivalent to removing one of the two microphones in the Transfer Function Method. The sketch of impedance tube with one microphone is shown in Figure 3, where the same impedance tube is used in Transfer Function Method, but one microphone is used to measure the sound pressure value. For this method a test is performed with the same microphone in each of the two microphone locations. The benefit of using one microphone is that there is no calibration required since the same microphone is used through the entire test. This technique can be performed using two different techniques. One is with fixed microphone locations and the other is with variable microphone locations. The fixed location will be studied because it can be used with the two microphone impedance tube. The other would require a different tube entirely. The sound at the two locations needs to be recorded sequentially with a sound source that is unchanging. It is recommended to use a deterministic signal as the sound source. Then the Fourier transform can be used to measure the frequency response.

The sound pressure in the tube with one fixed microphone can be expressed as

$$\mathrm{p}(\mathrm{x},\omega,\mathrm{t}) = \mathrm{p_i}(\omega,\mathrm{t})\mathrm{e}^{-\mathrm{ikx}} + \mathrm{p_r}(\omega,\mathrm{t})\mathrm{e}^{\mathrm{ikx}} \qquad \cdots\cdots\cdots (8)$$

where k is the wave number which is equal to$2\pi f$ /c, ω is angular frequency which is equal to $2\pi f$.

The acoustic impedance can be calculated by the following equation

$$\mathrm{z} = \frac{\mathrm{p(x,\omega)\cos\ kl - i\rho cv\sin\ k(l-x)}}{\mathrm{\rho cv\cos k(l-x) - ip(x,\omega)\sin\ kl}} \qquad \cdots\cdots\cdots (9)$$

The specific acoustic impedance ratio can be expressed as

$$\frac{Z}{\rho c} = \frac{\mathrm{p(x,\omega)\cos\ kl - i\rho cv\sin\ k(l-x)}}{\mathrm{\rho cv\cos\ k(l-x) - ip(x,\omega)\sin\ kl}} \qquad \cdots\cdots\cdots (10)$$

The reflection factor (R) can be solved as

$$\mathrm{R} = \frac{\frac{\mathrm{Z}}{\rho\mathrm{c}}-1}{\frac{\mathrm{Z}}{\rho\mathrm{c}}+1} = \frac{\frac{\mathrm{p(x,\omega)\cos\ kl - i\rho cv\sin\ k(l-x)}}{\mathrm{\rho cv\cos\ k(l-x) - ip(x,\omega)\sin\ kl}}-1}{\frac{\mathrm{p(x,\omega)\cos\ kl - i\rho cv\sin\ k(l-x)}}{\mathrm{\rho cv\cos\ k(l-x) - ip(x,\omega)\sin\ kl}}+1} \qquad \cdots\cdots\cdots (11)$$

where l is the length of the tube, x is the distance between sample and microphone, ρ is the air density and c is the velocity of sound.

The sound absorption coefficient (α) can be calculated as follows:

$$\alpha = 1 - \left|\frac{\frac{\mathrm{p(x,\omega)\cos\ kl - i\rho cv\sin\ k(l-x)}}{\mathrm{\rho cv\cos\ k(l-x) - ip(x,\omega)\sin\ kl}}-1}{\frac{\mathrm{p(x,\omega)\cos\ kl - i\rho cv\sin\ k(l-x)}}{\mathrm{\rho cv\cos k(l-x) - ip(x,\omega)\sin\ kl}}+1}\right|^2 \qquad \cdots\cdots\cdots (12)$$

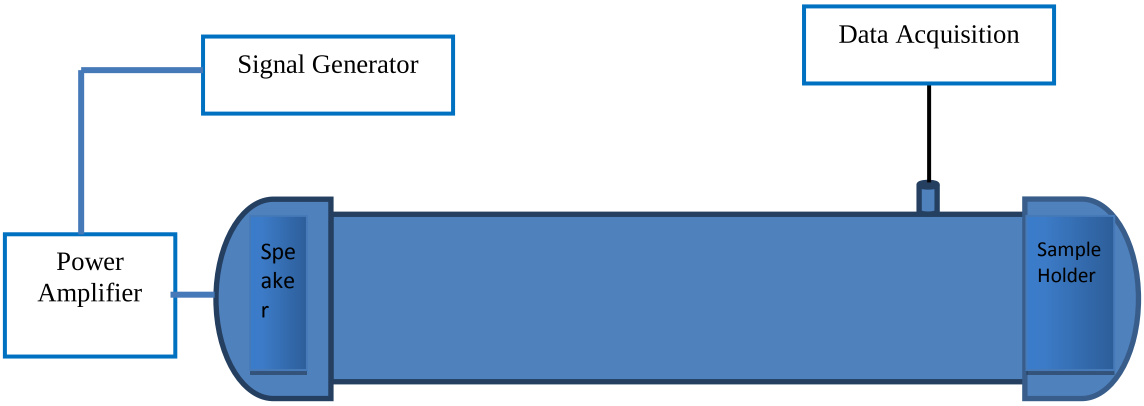


Figure 3 Schematic of impedance tube with one fixed microphone

Experimental Procedure

The experimental setup includes a computer, a data acquisition board, a speaker and a ¼ inch electret condenser microphone as shown in Figure 4. The loudspeaker was turned on for 10 minutes before starting the measurements (ISO 10534-2 recommendation) allowing temperature stabilization. An appropriate speaker was selected and it was placed at one end of the tube and the signal was fed to the speaker with the help of data acquisition board. The speaker was positioned in a column PVC pipe at the left end of impedance tube. The speaker was connected to the AUDIO OUT channel of NI myDAQ (National Instruments data acquisition device). In order to reduce the cost of the setup, electret condenser microphone is used in this research. It is omnidirectional microphone of very inexpensive and smaller in size. Microphone is sealed to the hole drilled in the PVC pipe and placed at the other end of the impedance tube. The microphone was connected to the AUDIO IN channel of the NI myDAQ board. The speaker was driven by NI myDAQ as the signal generator and the microphone captured the standing wave which was the superposition of incident and reflected wave from the test sample. The signal from the microphone can be acquired and can be written in the spreadsheet with the help of LABVIEW. The block diagram design in measuring sound pressure using NI myDAQ with LabVIEW programming is illustrated in Figure 5. The block diagram of data acquisition is depicted in Figure 6. Moreover, temperature of the surrounding had to be maintained constant throughout the experiment. The sample with diameter equal to that of impedance tube was placed above the surface of the rigid plate which was in the sample holder. Once the microphone response was recorded, the desired acoustic property was calculated in Matlab (Matrix Laboratory). In this research, material was analyzed at the frequency ranging from 100 Hz to 2000 Hz.

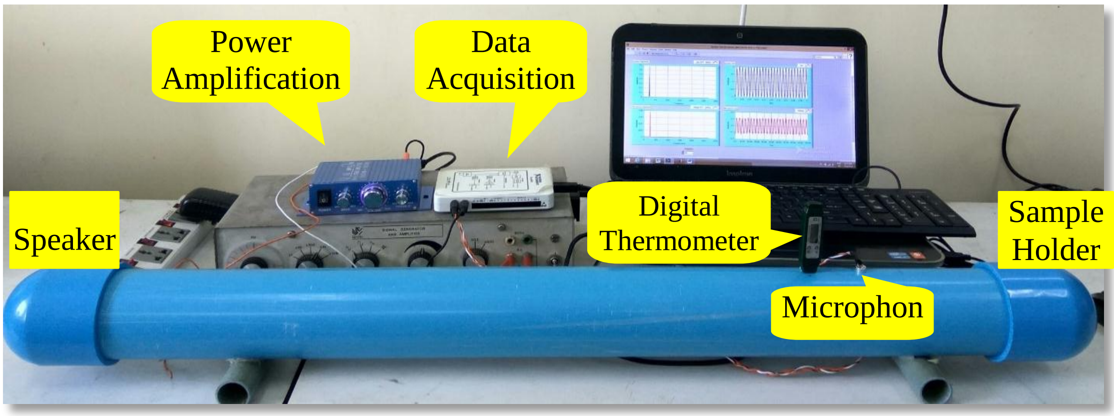


Figure 4 Experimental setup of impedance tube

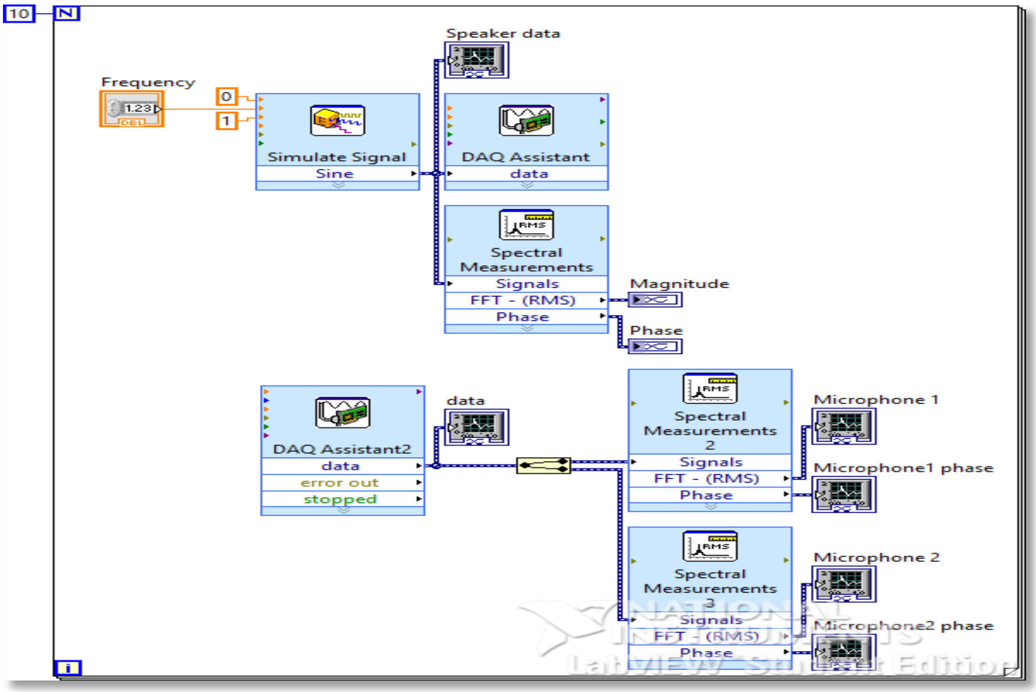


Figure 5 Block diagram design in measuring sound pressure of microphone

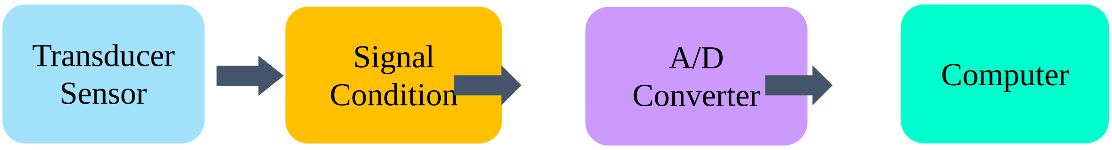


Figure 6 Block diagram of data acquisition

Results and Discussion

Sound Absorption Coefficient Measurement

The sound absorption coefficient measurement was carried out using one microphone impedance tube method. First, the data measured by commercial impedance tube (assume as standard tube) was compared with the data obtained from constructed impedance tube for the same glass sample. The sound absorption coefficient of glass which was measured by standard impedance tube and the value measured by the constructed tube are shown in Figure 7. The absorption coefficient of glass measured by constructed tube is much higher than that of the standard value in the frequency of 125 Hz and 250 Hz. On gradually increasing the frequencies, the sound absorption value obtained by constructed tube is closely matched with the standard value at the frequencies of 500 Hz and 1000 Hz. According to the validation results, we have confidence to use the constructed device.

The sound absorption coefficients of Myanmar wood samples obtained from this experiment are illustrated in Figure 8. According to the experimental result, the peak values of absorption coefficients of wood samples are found at 200 Hz, 800 Hz and 1100 Hz. Among them, acoustic absorption coefficient is maximum at frequency of 200 Hz. Low frequency noise, the frequency range from about 10 Hz to 200 Hz, has been recognized as a special environmental noise problem, particularly to sensitive people in their homes. At frequency about 200 Hz, the sound absorption coefficient is 0.1058 for Pyinkado, 0.1072 for Teak, 0.1048 for Kanyin, 0.1053 for Rubber and 0.1030 for Pine wood respectively. Teak wood has better absorption of sound compare with others at frequency of 200 Hz, 800 Hz and 1100 Hz. Therefore, the sound absorption can be changed with frequency of incident sound.

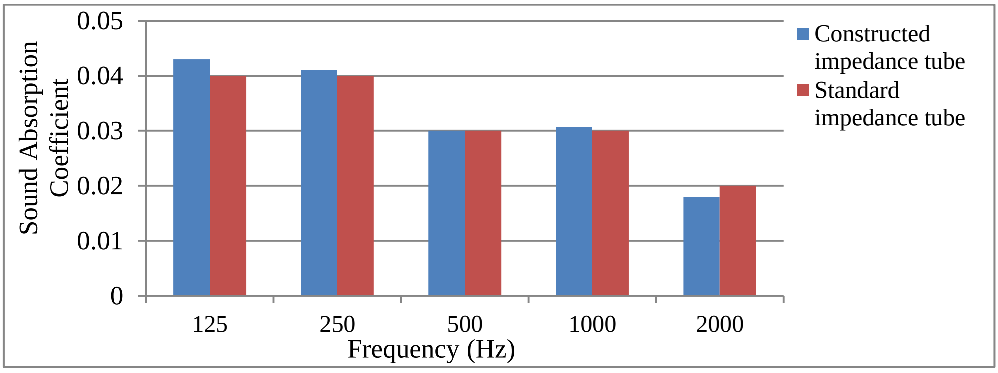


Figure 7 Comparison of sound absorption coefficient of glass using standard impedance tube and constructed impedance tube

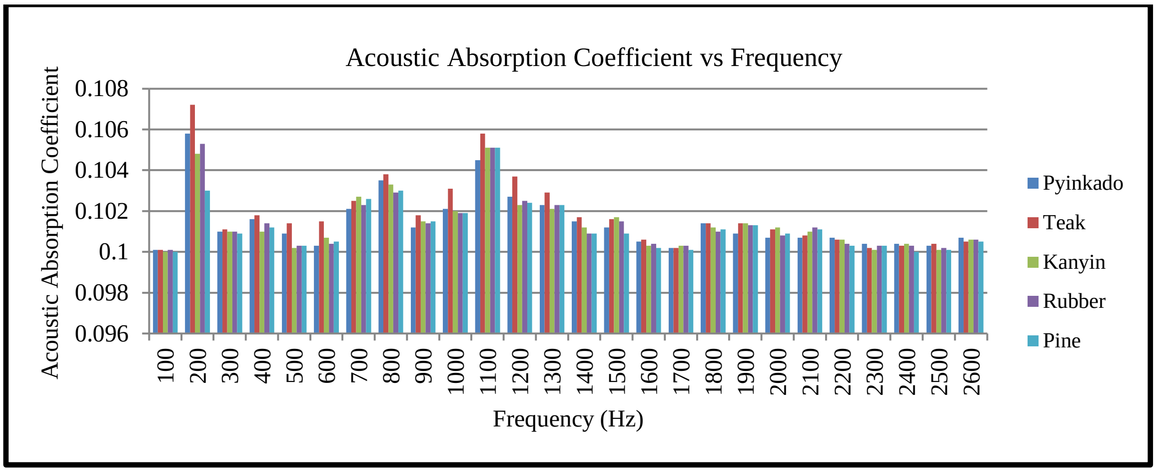


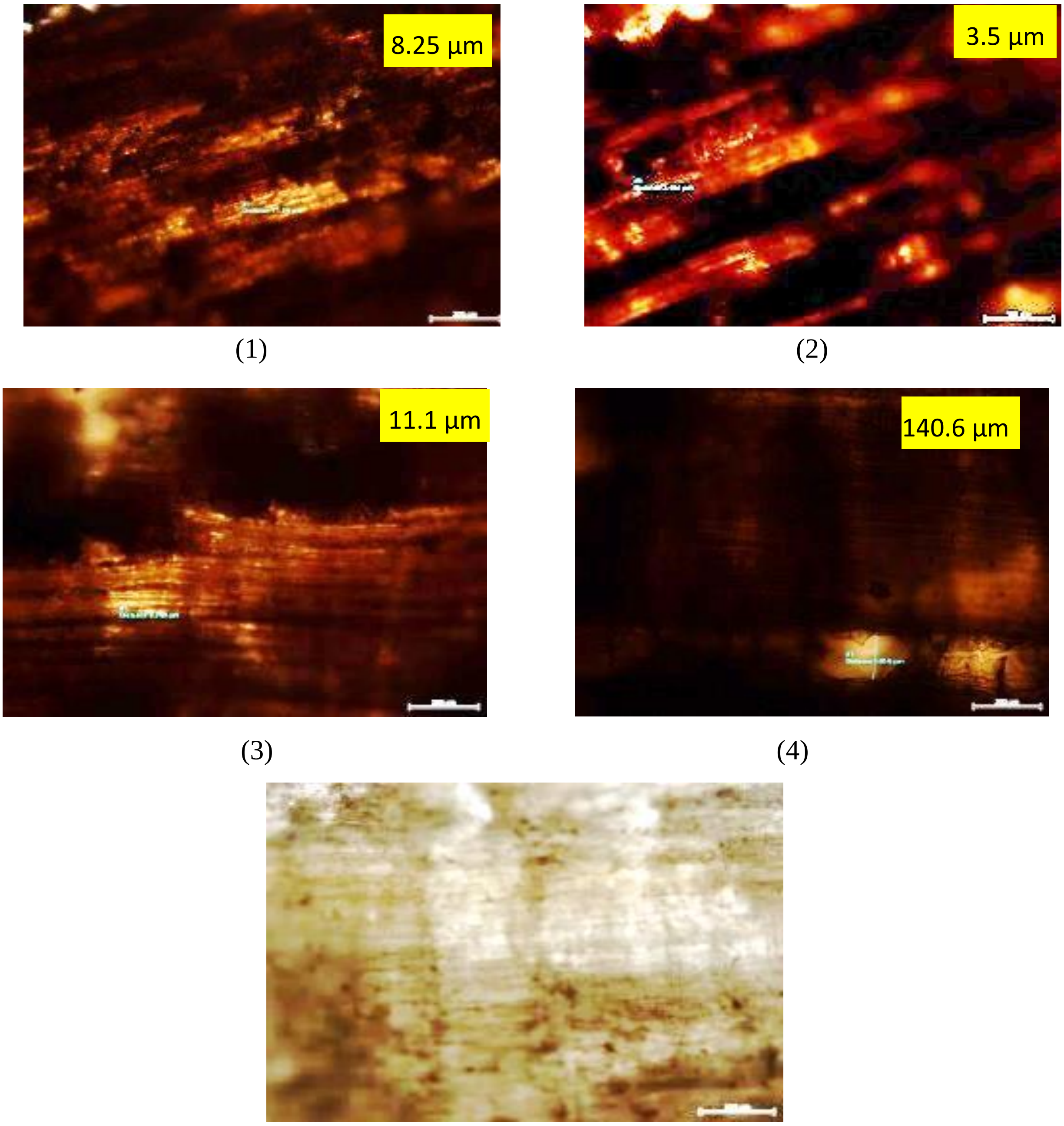
Figure 8 Comparison of acoustic absorption coefficient of Myanmar wood samples

Morphology Analysis

The morphologies of Myanmar wood samples were characterized by optical microscopy as shown in Figure 9. The number of vessels and vessel diameter of Myanmar wood samples are illustrated in Table 1. According to the measurement results, the sound absorption coefficient of wood samples depends on the density of vessel as well as vessel diameter of the sample.

Table 1 The number of vessels of Myanmar wood Samples

Samples	Pyinkado	Teak	Kanyin	Rubber	Pine
No. of vessels	261	345	139	65	Nill
Diameter of vessel	8.25 µm	3.5 µm	11.1 µm	140.06 µm	Nill



(1) (2) (3) (4) (5)

Figure 9 Optical microscope image of Myanmar wood (1) Pyinkado, (2) Teak, (3) Kanyin, (4) Rubber and (5) Pine

Conclusion

The sound absorption coefficients of five kinds of Myanmar wood such as Pyinkado, Teak, Kanyin, Rubber and Pine wood were investigated by one microphone impedance tube method. According to the experimental results, the sound absorption coefficients of wood samples are maximum at frequencies of 200 Hz, 800 Hz and 1100 Hz. Among them, Teak wood has better sound absorption coefficient in comparison with others. It can be concluded that the sound absorption coefficient of wood samples depends on the number of vessels as well as vessel diameter. Therefore, Teak wood has better quality than others not only in its durability, water resistance and beautiful texture but also in noise reduction properties to use as decorated material in building and furniture.

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