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Transmission Loss of Rigid Polyurethane Composite for Insulation Applications

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ABSTRACT

Rigid Polyurethane (PU) foams comprising various additive components were successfully synthesized to measure their sound performances. This study highlights the f sound transmission properties in PU composite when doped with different percentages of areca as a filler at 2.5%, 5%, 7.5% and 10%. In this study investigation on the effects of different percentages of area filler loading in PU foams. The characterization of sound absorption and transmission loss was obtained by using impedance tube technique according to ASTM E 1050 Standard. The method of transfer function and four microphones were used in measuring the sound transmission loss respectively according to the ASTM E 2611 Standard. In addition, the pore cellular structure and sound absorption coefficient of rigid PU foam revealed that the cell structure increase at composite 7.5% areca 0.3 mm, sound absorption coefficient increase at areca 0.3mm composite 10% and transmission loss were decrease at composite 7.5% 0.4 mm areca as an insulation in pipelines.

Key words: Rigid Polyurethane, Areca fiber, Sound Insulations, Transmission Loss.

1. INTRODUCTION

Insulating material is a type of material that resistive to the flow of electricity, heat or sound from one another and a range of bulky fiber materials to resist noise in a building. Acoustic barriers has been used widely used to control noise for various application, including in automotive vehicles, aero-space, and resident environment [1]. Sound insulation is the element or structures to reduce the sound transmission and it is measured over a range of frequencies. Normally, the sound insulation is about 100 to 3200 Hz and need to compare into the area of dividing part.

Commonly, the damage to the material caused by noise has been a significant concern; however, it can be controlled by two approaches. The first method is to control the source of noises, which means eliminating or reducing it to the safe level using the appropriate systems or facilities. It is effective useful measure, but there is currently no technology capable of control all the noise sources. In the building applications, the sound wave can be eliminated on the ways of transmission by use sound absorption and sound insulation materials [2]. The material's sound insulation capability is typically determined by sound transmission loss (TL) defined as the differences between the transmitted sound power and the sound power level of the incident wave. The noise reduction coefficient is the average of an acoustic materials absorption coefficient at a specified set of frequency mostly at 250 Hz, 512 Hz, 1024 Hz, and 2048 Hz accordance to the type of tube and acoustic measuring instrument used for the test [3].

Lightweight porous material such as polyurethane (PU) foams are comprehensively used as noise control materials in the automotive industry and these material have play the roles in promoting acoustic performance such as sound absorption, vibration damping and acoustic attenuation. Therefore, PU is important to sound absorbing material to its relatively low density and high porosity [4]. However, the most attractive composite materials is natural fibers due to its ecological and economic benefits. These composite materials are widely applied in many industry such as in building, aerospace, automotive and packaging. In addition, the polymer composite also used for sensor applications [5].Numerous studies have been studied to explore the utilization of natural fibers, especially leaf fiber materials [6].

Rigid polyurethane foam is mainly used as a sound insulation materials with a large scale of polyurethane production [7]. Rigid polyurethane foam has good property such strongly crosslinked, cross pore materials produced by treating polyester and polyester polyols with polymer MDI grades. The mechanical properties and the processing characteristics of polyurethane foam can be varied over a wide range by using a number of available raw material components and combinations options. The density of rigid PU foams were performed by adding physical blowing agents by formation of carbon dioxide, which is formed by the reaction of water with isocyanates [8].

Many countries are enforcing the regulation of energy saving buildings and demand for better insulating materials consumptions. The existing insulating panels are made from polystyrene extruded or expanded which mineral wool, or wood wool as compared to panels made from rigid polyurethane and polyisocyanurate foams also known rigid PU/PIR foam can better serve for the insulating materials.

For good insulating properties, rigid PU foam is the material of choice for thermally insulating refrigerators which has the highest energy efficiency. Today, more than 95% of refrigerators manufactured was installed with insulated PU, and this innovation is to optimize the energy consumption. In the preparation of insulation, the liquid of PU components are then injected into the cavity, where they foam up and fill the hollow spaces. The insulating performances of rigid PU foam depends on its cell size. In overall, it can be said that the smaller the diameter of the cells, the lower the thermal conductivity and it'll have better insulating properties [8].

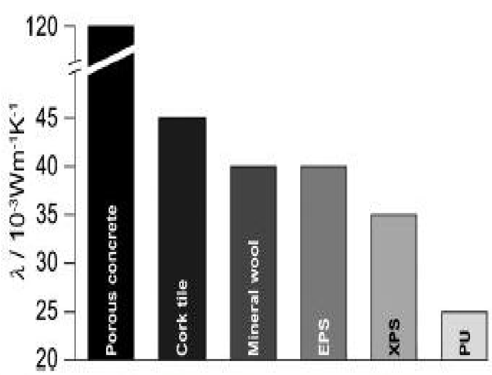

Figure 1: Values of various insulating material [7]

Areca is a type of Areca Catechu Linnaeus under the family palmeccea which is originated from the peninsular of Malaysia and East India [9]. There are several products like fiber, nuts, oil and rice straw [10]. Areca originated from the husk of hard fibrous material that covering and constitutes about 60-80% of the weight areca fruit. The properties of areca fibers properties are mentioned in Table 1 [11].

Table 1: Density property of Areca leave

Diameter	Average length of fiber	Density (g/cm^3)
0.285-0.89	29-38	1.05-1.25

Areca is a natural fibers which are available in abundant amount. Areca Catechu shell is a rigid fibrous material. The chemical com-position and the physical attributes of areca fibers are easily accessible. The tensile strength of areca fibers ranges from 147-322 MPa which is higher compared to other fibers like coconut fiber (95-230 MPa) and palm fiber (80-248 MPa). Hemicellulose is mainly responsible for the moisture absorption which can create problem in the performance of composites prepared from it. The amount of these hemicelluloses are 13-15.42% in the areca fibers which is less compared to other fibers like flax (18.6-20.6%), kenaf (20.3%), jute (14-20%) and abaca (20-25) [9]. Hence the comparison of various properties of areca fibers with other fibers states that out of all the natural fibers, areca fibers serves to be a promising material in incorporating to composite arrangement.

Areca fibers can be produced at a low cost and subsequently makes it a better product for a low-wage countries. They play a superior role compared to the synthetic fibers in incorporating it as the reinforcement in the production of composites as the fibers itself are biodegradable. These fibers have a great thermal and acoustic insulating properties. Areca fibers are lightweight compared to other synthetic fibers, eco-friendly, non-toxic and sustainable which further gives the waste management solution.

2. METHODOLOGY

2.1 Sample preparation

The raw material used, an Areca leaf fiber were supplied from Eco Green Sdn. Bhd. which initially chopped to short length and then shredded and grind using RT-34 1HP Table Type Pulverizing Ma-chine. The short length of 0.3mm and 0.4mm were found after blended and sieve in pulverizing machine.

2.2 Rigid PU production

There are five different types of rigid PU foam composite were designed and developed in this study. The fabrication of Rigid PU composites doped with different weight ratio of Areca leaf fiber size of 0.3mm and 0.4mm which is 0%, 2.5%, 5%, 7.5 % and 10%, respectively. Similar with many literatures, the rigid PU foam composites were produced manually using a mould [12-13]. The polyurethane (PU) foams were produced using a polyol/MDI ratio of 100/102 [14], and 100/100 ratio of OH/NCO according to Explorer Composite Sdn Bhd. The fabrication of rigid PU foams samples was perform by open mould casting technique. Next, polyol/MDI was start with stirred with a handmixer at constant speeds in a container and then mixed with distilled water and areca leaf at different percentages until homogenous mixture. Then, the OH/NCO was poured into polyol/MDI mixture and continue stirred. The mixtures were then immediately poured into a closed mould before the foam is expanded out. The PU foam composite can be removed from closed mould after 15 minutes and left to cure at the room temperature around 1 day.

2.3 Characterization Method

The morphological structure of rigid PU foam composite was carried out using an Advanced Microscopy Simplified model BX53M/BXFM Olympus Stream Software. The morphology samples were operate with light intensity and using 5x, 10x and 20x of magnification as per ISO 800 standard.

The sound absorption and transmission loss of rigid PU composite samples were tested according to ASTM E1050 and ISO 10534-2. The sound absorption test was conducted at the frequency range of 100-1600 Hz. The 100 mm diameter of rigid PU composites samples used to examine the sound absorption coefficient and transmission loss at low frequency ranges [15]. Transmission loss was measured with four microphones positioned at upstream and downstream position relative to the rigid PU composite sample. The microphone spacing positioned at s1 and s2 is 0.05mm while distance from spacing to microphone L1 is 0.1mm and L2 is 0.33mm, respectively.

3. RESULT AND DISCUSSION

The present of waster in polymeric matrix was highlight as a important factor during fabrication of rigid PU foam composite. This is due to water can act as a chemical blowing agent and released the carbon dioxide (CO_2) when it reacts with isocyanate during fabrication process. Hence, to promote the effective rising foams, the extra distilled water was added in polyol. The result shown that by adding distilled water the foaming cell is better compared when there's no distilled water present. Therefore, a new blend ration of rigid PU composite formation was successfully develop doped with areca fiber as a fillers. Figure 1 shows the average pore size of rigid PU foam composites increased with increasing of amount of filler loadings. In observation, the open cell cellular structure with a round shape and interconnected pores. The open-cell structures has several small open-windows situated on the cell wall, and which allow the struts to form between the open windows.

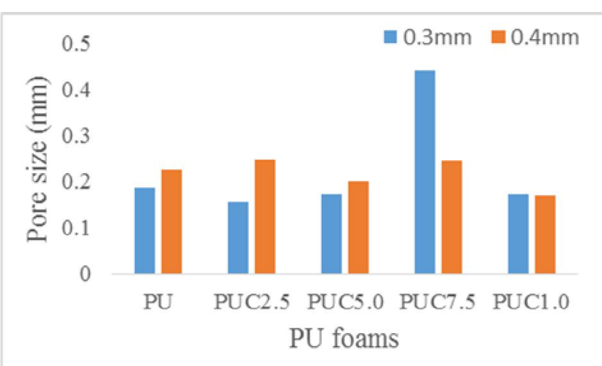

Figure 2: Average size pore of PU Rigid foams of 0.3mm and 0.4mm

Figure 2 shown the average pore size of 0.3mm and 0.4mm areca as a filler. In average pore size PU foams 0.4mm shows slightly increase from 0.2 mm and then suddenly drop to 0.15 mm. The PU0.75 shows the highest average pore size for 0.3 mm as compared to others. However, PU2.5 displays the lowest of pore size as com-pare than others PU foams. The rigid PU foam composites were decided to dope until 10% of filler due to composites were found not effectively rise once the loading more than 10%. This is due to additional fillers caused a rapidly increased of viscosity in the mixture during foam formations. The increasing of viscosity in mixtures causes the specimen no longer to forming properly. Besides, it was noticed that added fillers to rigid PU foam may increase the foam formation time.

Figure 3 shows the ability of rigid PU foam composite doped with areca fiber to act as sound absorbing materials at the low frequency range of 100-1600 Hz. At low frequency level where human sensitivity to noise is high, rigid PU foam composite shows gradually increasing of sound absorption coefficient, α with increasing of filler loading. From the observation the curve from Figure 3, the highest ability for normal incident α is approximately equal to 0.63 at 1250Hz with 10% areca fiber loading. The α of 0.63 indicated only 63% of the incident sounds waves are absorbed by the noise absorbing material whereas all of the sound waves are absorbed when the coefficient reaches a value of 1. However, the α increased by 1.8 % at the low frequency level due to the larger size of porous cell, thus reducing the absorption coefficient at low frequency level. This is due to the areca fiber has ability to absorb noise in the low frequency level. Hence, the rigid PU foam composite was able to give high α at low frequency level suitable for pipes insulations applications.

According to Anika et al., (2012) mentioned that the noise coefficient increase with the smaller fiber diameter in such a way the impermeable size much smaller as compare to sound wavelength [16]. As refer to Figure 3 and Figure 4, in comparison of size of areca filler loading which is 0.3 mm and 0.4 mm, the α show the highest value at the low frequency range between 1100 to 1600 Hz. This is due to the increasing of filler loading gives more chance to contact with sound wave. Moreover, this also occurs due to increasing of vibration of friction of air particle when the sound energy transform to heat energy in composite structure.

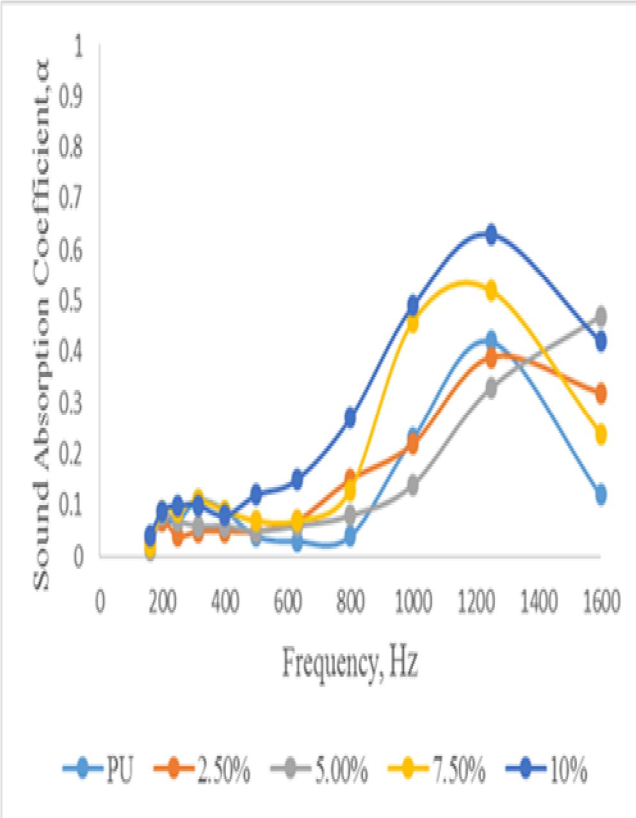

Figure 3: The sound absorption coefficient of PU at 0.3mm Areca leaf fiber

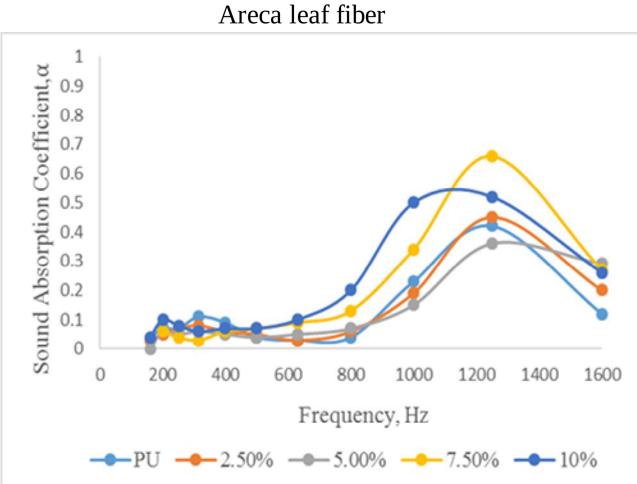

Figure 4: The absorption coefficient of PU at 0.4mm Areca leaf fiber

The transmission loss of Rigid PU foam with different ratio filler loading are shown in Figure 5 and Figure 6. The transmission loss slightly decrease with decreasing of areca filler loading at the low frequency ranges of 1600Hz. However, a striking reduction for rigid PU foam was located at about 315 Hz. This is due to the ability of pure rigid PU and 2.5% areca filler loading has full sound absorption. This also due to the small amount of filler loading enhance the sound absorbing materials. The sound insulation performance was opposite as compared to the sound absorption coefficient. Figure 5 shows PU composite doped at 2.5% Areca fiber gives the lowest sound transmission loss at 1600 Hz. Meanwhile, in Figure 6 the lowest sound transmission loss at 1600 Hz PU is PU pure foam. PU composite at 10% Areca fiber shows started transmit losses at 100 Hz drop until 315 Hz and suddenly increase and then drop 15.8 at 1600 Hz. This is possibly due to the larger amount of areca filler loading in rigid PU foam gives the high transmission loss and low sound absorption.

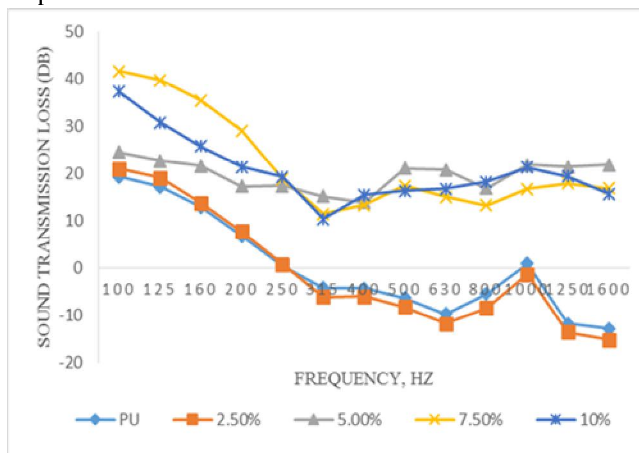

Figure 5: The transmission loss of various foam 0.3mm Areca

Moreover, the morphological structure of rigid PU foam composites exhibit almost all the pores structure are closed and interconnected between each other. On additional of areca fiber into rigid PU foam, the connected pores are slightly occupied in struts and sometimes blocked the sound waves. The sound waves would reflect when it meets areca fiber in its propagation path, thus extending the transmission route in the rigid PU foam. There is an increase in energy loss due to transmission. This is leads to increase in the sound absorption coefficient especially in low frequency.

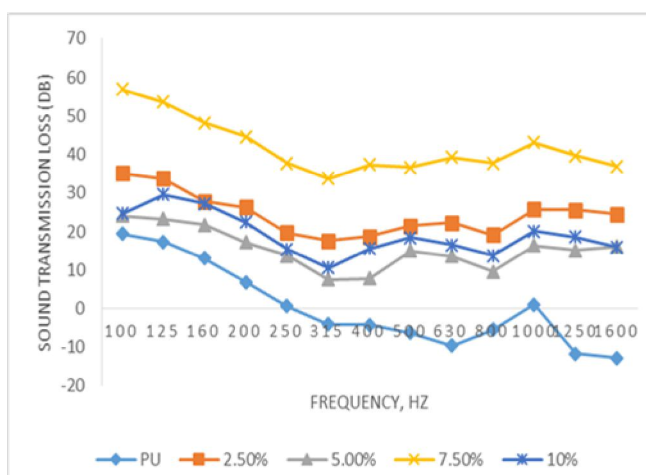

Figure 6: The sound transmission loss of various foam 0.4mm Areca

4. CONCLUSION

In this study, the ability of rigid PU composite doped with different ratio at 2.5%, 5.0%, 7.5% and 10% of Areca fiber to absorb sound was successfully examined by sound absorption test. The sound absorption performance of PU foam is very satisfying at low at 1600 Hz. Moreover, with adding Areca fiber in PU composite, the sound absorption coefficients increase at low frequency at 1600 Hz frequency. The pore cell structure at of rigid PU foam were decrease, the performance for PU foam in-creased. Besides, the transmission loss revealed that PU composite doped with 7.5% areca shows the best sound insulation characteristics. This advantages make Rigid PU composite doped with areca fiber a kind of attractive materials for many applications in sound insulation such as automotive engineering, aerospace and construction fields. In addition, as an agriculture waste, the areca fiber is sure to meet sustainable development requirements toward to reduce environmental issues.

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