Improving sound absorption property of polyurethane foams doped with natural fiber

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Abstract. This study investigates the acoustics behavior of wood fibre filler of Red Meranti - filled polyurethane foam as a sound absorbing material. Three different thicknesses have been selected which is 10 mm, 20 mm and 30 mm. By choosing percentage loading of Red Meranti (RM) wood fibre of 5%, 10%, 15% and 20% added with polymer foam is namely as polymer foam (PF) composites of $PF_{5\%}$, $PF_{10\%}$, $PF_{15\%}$ and $PF_{20\%}$. The sound absorption coefficient (α) and pore structure of the foam samples have been examined by using Impedance Tube test and Scanning Electron Microscopy (SEM). The results revealed that the highest thickness of highest filler loading ($PF_{20\%}$) gives higher sound absorption coefficient (α). The absorption frequency level is observed at 0.9922 and 0.99889 which contributed from low and high frequency absorption level respectively. The smallest pores size structure was observed with highest filler loading of PF. The higher the thickness and the higher the percentage loading of wood filler gives smaller pore structure, consequently, increased the sound absorption coefficient level.

1. Introduction

The need of good surroundings and residentiary security is expanded, as the issue of unsafe noise has grown into severe [1]. As natural resources come limited, numerous researchers and manufacturers are starting to study and use different sustainable resources, for example, the generous and low cost vegetable oils, which serve a main possible origin of chemicals [2]. Recently, wood-based construction manufacturers have produced an excessive amount of wood dust. Previous studies have investigated that the characteristics of particle board created from fine particle were superior to a board that created from coarse particles [3]. This rural natural material with its accessibility and specific property created an outstanding goal to enlarge the use of green resources. The examples of property are as sound absorbing materials.

The sound absorbing materials absorb most of the sound energy striking them and reflect very little [4]. Hence, it has been observed to be extremely helpful to reduce noise [5]. Previous studies had done an approach to promote more materials and machinery with sound absorption characterization [6,7] with a great rate of sound absorption coefficient are normally porous [4,8]. Meanwhile,   polymeric materials are notable materials suitable for many mechanical operations and thoroughly examined for

acoustics foams [2,9]. Polyurethane foam of palm oil was synthesized, crosslink and doped with an eco-natural filler of rubber waste or sawdust powder from a previous study [2,10]. This study uses Red Meranti wood dust (RM) as filler due to its availability as waste from the furniture manufacturer. Motivation from research work on the use of impedance tube analysis of the bamboo fiber tests shows identical characterization to the glass wool [6]. Thus, the bamboo material framed inside fiberboard offer a better sound absorption characteristic in comparison to plywood material of the same density [3,6]. The absorption coefficient is a practical idea when using geometrical acoustic approach to figure out the development and reduce of sound energy in a room [10]. Therefore, the objective of the studies is to investigate the influences of wood dust filled in polyurethane foam as sound absorbent materials.

2.   Methodology
2.1   Foam preparation
The foam samples were prepared by once shot method. RM (<200µm size) with the percentage of 5%, 10%, 15% and 20% respectively were used as filler**.** The polyol is reacted with cross-linker with correct proportion ratio of 1.0:0.5 (wt/wt %). The formulation used as shown in **Table 1.** The foams are made with an uncured polyol, mixed with isocyanate and then cast into a mold. The mixture is left to cure at room temperature for at least 6 hours. After completely cured, the foam samples thickness is measured using Teflon mold of 100 mm diameter and 28 mm diameter. This is to cut the foam samples in accurate thickness and diameter as shown in Figure 1 [2]. The thickness is cut in 10 mm, 20 mm and 30 mm using a blade and labelled as neat polymer (PU) foam. The added filler of RM in the polymer is namely as polymer foam composites (PF).

Figure 1. Polymer foam composite (PF).

Table 1. Proportion ratio of polyol, wood filler and cross-linker

Samples	Mass (g) polyol/filler/isocyanate
Neat polymer foam (PU foam)	30/0.0/15
PF$_{5\%}$	30/1.5/15
PF$_{10\%}$	30/3.015
PF$_{15\%}$	30/4.5/15
PF$_{20\%}$	30/6.0/15

2.2   Impedance tube test
The impedance tube consists of an adjustable filter, propagation tube, large sample tube 100 mm diameter, small sample tube 28 mm diameter and two-microphone method and a digital frequency analysis system for the measurement of the normal incidence sound absorption coefficient and normal

specific acoustic impedance ratios of materials [11]. The samples were tested by using impedance tube test according to ASTM E1050 for horizontally mounted orientation sensitive materials for the frequency range of 0-6000 Hz [12].

2.3   Scanning Electron Microscope (SEM)

The surface of neat PU foam and PF foam samples was gold coated at 25 mA plasma current and 2 Pa of chamber pressure to make them as conducting samples [1,10]. The morphological surface structure with interconnected pore of different sizes images were examined by using SEM of JEOL-JSM6380LA operates at 10 kV at 40 μm magnifiers under high vacuum [11].

3.   Result and Discussion

A porous material is efficient from the sound absorption perspectives when its thickness is roughly one-tenth the wavelength of the incident sound [13]. Meanwhile, the optimum absorption happens at a resonance frequency of a quarter the wavelength of the incident sound [13,14]. Due to this, the sound absorption coefficient is affected by the material thickness. An increase in sound absorption especially at low frequencies when the material thickness increases but at high frequencies, material thickness has a lower impact on sound absorption [15].

Figure 2. shows the graph for neat PU foam and PF with thickness 10 until 30 mm and percentage loading of 5%, 10%, 15% and 20% of the sound absorption coefficient in the frequency range of 0–6000 Hz. From the graphical representation, $PF_{5\%}$ with a thickness of 30 mm shows higher values of the sound absorption coefficient (α) at low frequency with 0.9038, and high frequency with 0.9981 as shown in Figure 2. (a). Meanwhile, Figure 2. (b) shows $PF_{10\%}$ with a thickness 30 mm gives the highest α at the low and high frequency with 0.9529 and 0.9933 respectively. In Figure 2. (c), $PF_{15\%}$ with thickness 30 mm gives the highest α at the low and high frequency with 0.9636 and 0.9909 respectively. Besides that, $PF_{20\%}$ with thickness 30 mm gives the highest α at the low and high frequency with 0.9922 and 0.9989 respectively as shown in Figure 2. (d).

From the result, $PF_{20\%}$ with thickness 30 mm gives better α as compared to other PF. The result indicates that α is dependent on its thickness and percentage loading. The higher the thickness and percentage loading of polymer foam composites, the highest the α of that particular frequency will be. This is due to the larger the thickness and percentage loading of polymer foam composites at particular frequency lead to more energy can be damped [13,14]. This can be proven by the cellular interconnected pore structure of each polymer foam composites.
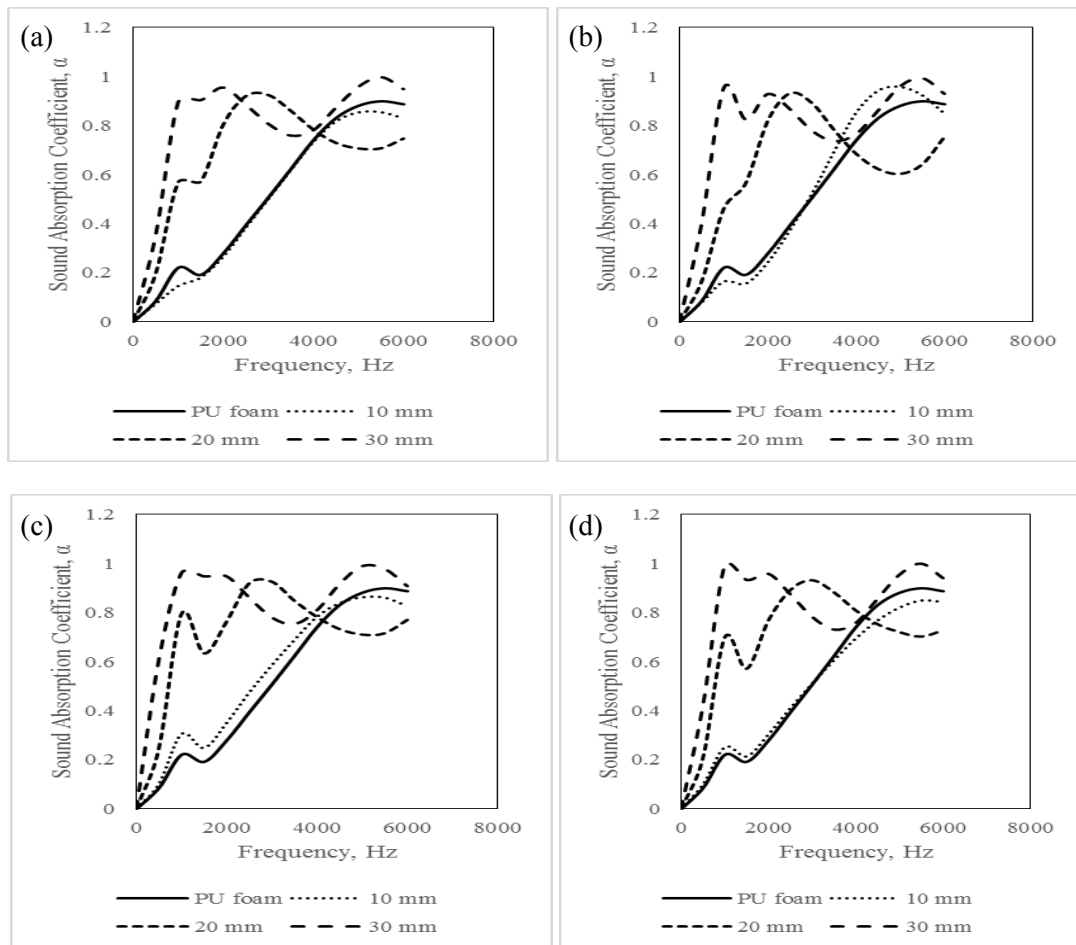
Figure 2. Sound absorption coefficient for different thickness of polymer foam composites with different percentage loading of wood filler: (a) $PF_{5\%}$; (b) $PF_{10\%}$; (c) $PF_{15\%}$; and (d) $PF_{20\%}$.

Number and size of the pore are among of the factors that need to be considered on the sound absorption mechanism in porous materials studies [13,16,17]. Sound should enter the porous material here and it will damp itself, thus, the surface of the material should be enough open pores to allow this happens [16]. **Figure 3. (a)** until **Figure 3. (b)** shows pore structure of $PF_{5\%}$, $PF_{10\%}$, $PF_{15\%}$, $PF_{20\%}$ and neat PU foam. $PF_{20\%}$ gives smallest average interconnected pore size compare to neat PU foam as shown in **Table 2.** The smallest interconnected pore structure gives better α whereby more collision occurs between the sound wave and cell wall, thus, created a longer path of reflection and refraction of energy [18] in the internal structure. This study has observed that the polymer foam composites have different pore structure with several interconnected pore sizes which will affect the value of α.

Table 2. Average pore size of PU foam and PF foam

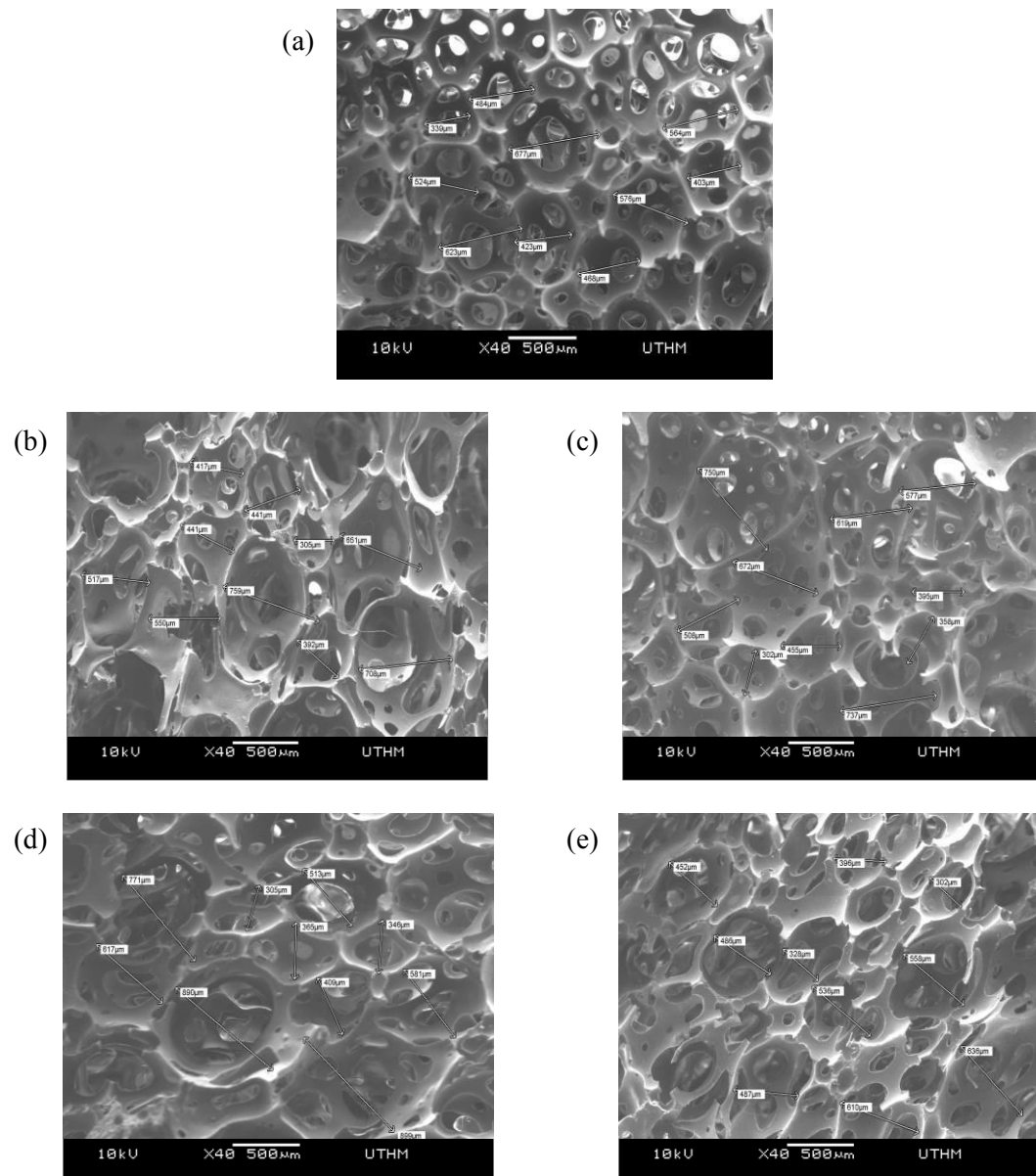| Samples	Average pores size (mm)
Neat PU foam	0.5081
$PF_{5\%}$	0.5696
$PF_{10\%}$	0.5373
$PF_{15\%}$	0.5181
$PF_{20\%}$	0.4795

Figure 3. Interconnected pore structure of PF: (a) neat PU foam; (b) $PF_{5\%}$; (c) $PF_{10\%}$; (d) $PF_{15\%}$; and (e) $PF_{20\%}$

4.   Conclusion

The polymer foam composites filled with RM as sound absorbent materials were studied. The thickness and the percentage loading of wood fiber in polymer foam composites (PF) contributed to different level of frequency absorption level; low – 0-1500 Hz to high frequency absorption level (1501-6000Hz). The 30 mm thickness of $PF_{20\%}$ shows highest sound absorption coefficient at 0.9922 and 0.9989 at low and high absorption frequency level; Hz. $PF_{20\%}$ also shows the interconnected smaller pore structure which increased the sound wave to enter the pore and contributed to the increased of the sound absorption coefficient. This is to highlight that the smaller the interconnected pore the higher the amount of pore which creates a longer path of reflection and refraction of energy and able to damp the noise which contributed to the highest sound absorption coefficient. Meanwhile, the higher the thickness of PF shows divided and varied the frequency absorption level, Hz.

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