Sound and Vibration Damping Properties of Water Retted Kenaf Bast Fiber (WKF) and Poly (Butylene Succinate) PBS

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Abstract. Nowadays, considerable attention has been paid on the utilization of natural materials to reduce the carbon emission from material synthesis. In this study, the sound and vibration damping properties of natural material based Poly Butylene Succinate(PBS) and Water Retted Kenaf Bast Fiber(WKF) were explored and characterized. The goal is to characterize the sound absorption and damping properties of the PBS and WKF at difference materials percentage. The (material)PBS and WKF are produced by using Compression moulding machine model Gotech GT-7014-H and the sample thickness is 3 mm. The vibration damping measurement of the material is carried out based on the free vibration method technique. It is observed that the damping factor is obtained is 0.0469 for PBS material. The measurement of the sound absorption coefficient of the PBS and WKF is carried out using the impedance tube. The result shows that the maximum sound absorption of 0.305 was observed at a frequency of 642 Hz for PBS material. Whereas Tensile Strength, for PBS material shows 26.33 MPa. These results suggest that the PBS could be a viable candidate for applications which need good sound and vibration properties.

1. Introduction

Noise pollution has become a new pollution source that caused the bad influence on the environment and human health. Nowadays, researchers have carried out various noise control methods for investigating the issue such as passive and active control [1]. The research focus is mostly on natural fibers such as kenaf, ramie and jute reinforced composites since this particular material have a good mechanical property, lightweight, environmentally friendly and biodegradable [2,3].

Multiple layered coir fiber absorbers involving air spaces and micro-perforated plate has been studied both through simulation and experiments [4-5]. Ersoy and Kucu [6] studied the absorption performance of industrial waste tea leaf fiber and found that the absorption coefficient of the fibers increases significantly when backed with a single woven cotton cloth. Yang and Li [1] studied three types of natural fibers which are ramie, flax and jute. They found that those natural composites had satisfying noise reduction ability similar to that of the synthetic fibers. Bastos et al., [7] proposed noise control panels which made from vegetable fibers consisting of coconut, palm, sisal and acai. The performance of vegetable fibers could be greater in certain cases when compared to synthetic acoustic foam materials. Besides, Xiang et al., [8] studied the sound absorption properties of kapok fibers where the result showed that kapok fibers have
similar acoustics performance with the combinations of commercial glass wool and cotton fibers although the bulk density of kapok fiber is lower.

Sugarcane waste fibers was studied by Putra et al. [9]. In research found that the sound absorption coefficient is comparable with those of commercial synthetic fibers. The review of previous research shows that there have been many studies performed on natural material that resulted good sound-absorbing and vibration damping properties [10]. These natural materials could essentially be grown for manufacturing composites, in turn providing such benefits as being both biodegradable and recyclable.

This study aimed to explore the mechanical properties, sound absorption coefficient ability and damping ratio of water retted kenaf bast fiber and polybutylene succinate.

2. Experimental Measurement

2.1. Material preparation
Polybutylene succinate (PBS) with trade name Bionolle #1020 is produced by Showa Highpolymer Co. Ltd, Japan. The density of this polymer is 1.25 g/cm³ and the melt flow index is 26 g/10min (at 190°C and 2.16 kg load). PBS was supplied in dry pellet and has a melting temperature (Tm) ranging from 120-140 °C. Water retted kenaf bast fiber was supplied by Lembaga Kenaf & Tembakau Negara (LKTN). The fiber length distribution ranging from 1-3mm. The fiber density is 1.14 g/cm³.

2.2. Preparation of the composites
Initially, WKF and PBS were dried in an oven at 50°C for 24 hours and kept in desiccators. Next, the composites were mixed using rotating double-winged rotors (POTOP). The temperature of the compounding chamber was set at 165°C. Generally, the temperature of the chamber was allowed to stabilize for approximately 3 minutes before it was loaded with PBS pellets. Then, the fiber was gradually added to the chamber under a low rotor speed (10 rpm). Once all of the fiber was fed in, the compounding process was continued at a rotor speed of 50 rpm for 5 minutes before being discharged. The composite compounds were compression-moulded at 165°C into dumbbell shape specimens ASTM D638 type I. with a compression-moulding machine Gotech (China). Figure 1 shows the compression mold machine that used in this research. The moulding cycle involved 5 min of preheating. without pressure, 3 min of compression under 50-ton compressive load, and 5 min of cooling under the same load. Before testing, the moulded specimens were kept in desiccators and conditioned at room temperature for at least 24 h. Table 1 shows the details formulation of the composites.

| Designation   | PBS (wt. %) | WKF (wt. %) | Weight (gram) |
|---------------|-------------|-------------|---------------|
| PBS           | 100         | 0           | 3.25          |
| 90PBS10WKF    | 90          | 10          | 3.73          |
| 80PBS20WKF    | 80          | 20          | 3.6           |
| 70PBS30WKF    | 70          | 30          | 3.48          |
| 60PBS40WKF    | 60          | 40          | 3.36          |
2.3. Sound absorption coefficient measurement

The Sound Absorption Coefficient of each sample was measured by utilizing of the impendent tube, LMS Scadas Mobile, LMS Software (LMS Sound Absorption Coefficient) and two Microphone units (Grass 46AE) as indicated in figure 2. The plunger at the back of the impedance tube is functioned to control the air cavity gap. The air cavity was set 50 mm for this experiment. A loudspeaker is used as a sound source on the impendent tube and it is placed in front of the impendent tube as shown in figure 2. It generates the broadband random sound waves and the sound waves propagating as plane waves in the tube hit the sample, get partially absorbed, and subsequently reflected. The acoustical properties of the test sample were tested in the frequency range of 50–1550 Hz. For this experiment the size of each sample was 34.8mm diameter and 3mm thick. The detail of the samples used with a different percentages of PBS and WKF is shown as in figure 3.

Figure 1. Compression molding machine model Gotech GT-7014-H

Figure 2. The setup experiment of the Sound Absorption Coefficient.

Figure 3. Sound Absorption Coefficient test Specimens.
2.4. Vibration damping factor measurement.
Free vibration method is used to measure damping factor as shown in figure 4. The specimens were cut to desired size of 165mm x 12mm x 3mm. In figure 5, a different specimen of the percentage of PBS & WKF is used for damping factor measurement. The specimen was mounted on a cantilever beam structure and fastened using a fixture. An accelerometer (Dytran, 3224A2) with a sensitivity of 2.56 mV/g mounted at the end of the specimen. Before measurement, each accelerometer was calibrated using vibration calibrator. The signal output was process by LMS Scadas mobile data acquisition linked with LMS Test Xpress software on the personal PC.

![Figure 4. Vibration damping test set up](image)

![Figure 5. Vibration damping test specimen.](image)

Figure 6 shows the vibration response of the specimen over time. The damping factor is calculated by taking the highest value and the lowest value at the top of the graph in the obtained waveform. Then take a few peaks of the graph to calculate the damping factor ($\zeta$) and the obtained values will be included in equations 1 and 2.

\[
\delta = \frac{1}{\eta} \ln \left( \frac{Y_0}{Y_n} \right) \\
\zeta = \frac{1}{\sqrt{1 + \left(\frac{2\pi f}{\delta}\right)^2}}
\]
2.5. Tensile measurement Set Up
The tensile strength, elongation and Young’s modulus and of the proposed composites were determined using universal testing machine model Instron 5969 (USA) at room temperature and 50% relative humidity. The dumbbell-shaped samples in accordance with ASTM D638 (Type I) with a thickness of 3 mm and width 12.7 mm have been tested at an extension rate of 5 mm/min.

3. Result and discussions
3.1. Analysis of sound absorption coefficient measurement
Figure 7 shows the results of the sound absorption coefficient (SAC) of materials with different percentages of PBS and WKF at 3mm thickness. The graph shows that the SAC of purely PBS is higher compare to the composite material which is 0.305. The peak sound absorption was observed at 642 Hz and for all materials. The SAC of 60PBS 40WKF is 0.263, 0.257 for 70PBS 30WKF, 0.278 for 80PBS 20WKF and 0.147 for 90PBS 10WKF material. From all five advanced composite materials, PBS with higher sound absorption coefficient can be used accurately in sound absorption applications as an important design criterion. Besides, the mixing rate between PBS and WKF also affects the results produced by the Sound Absorption Coefficient.
3.2. Analysis of vibration damping factor measurement.

Figure 8: Damping ratio at different material, for thickness 3 mm.

Figure 8 shows the result of the damping ratio for specimen thickness of 3 mm for material with different percentages of PBS and WKF. From the results, the damping ratio for purely PBS material was 0.0469. Whereas the damping ratio for 60PBS 40WKF material is 0.0145, 0.0305 for 70PBS 30WKF, 0.021 for 80PBS 20WKF and 0.019 for 90PBS 10WKF. The results show that the PBS material has the highest damping ratio compared to the others.

3.3. Analysis of Tensile strength measurement.

Figure 9: Tensile strength and modulus of PBS/WKF composites at different fiber loading.

Figure 9: shows the effect of fiber loading on the tensile strength and modulus of PBS/WKF composites. In general, the neat PBS exhibits higher tensile strength than the PBS/WKF composites. The poor tensile strength of the composites especially at lower fiber loading i.e. 10 and 20 wt. % was due to poor fiber dispersion in the matrix as a result of incompatible fiber-matrix interaction. As already known, PBS is a hydrophobic polymer and kenaf fiber is hydrophilic and the incorporation of both materials in composites will result in poor interfacial adhesion and fiber-matrix interaction by Yatigala et al., [11]. However, the composites show increases of tensile strength from 23.34 MPa, to 25.56 MPa and 26.13 MPa when fiber loading increased from 10, 20 and 30 wt. %. The increases in tensile strength could be due to the reinforcing effect the WKF and also physical fiber-to-fiber entanglement of the kenaf fibers by Ismail & Ishak, [12]. The optimum fiber loading was at 30 wt. % and an abrupt drop was observed when the fiber loading further increased to 40 wt. %. The reduction of tensile strength at higher fiber loading was due to severe fiber agglomeration as a result of insufficient wetting of fiber by the polymer matrix by Han et al., [13]. The fiber agglomerates will be a stress concentration points and will lead to premature failure of the composites. On the other hand, the addition of kenaf also increased the tensile modulus of the composites because of the
stiff nature of the WKF. The higher the fiber loading the higher tensile modulus of the composites. The consistent increment in the tensile modulus with fiber loading was probably due to the restriction of the polymer matrix mobility with the presence of rigid fibers hence make the composite stiffer by Hamma et al., [14]. As a consequence, the elongation at break of the composites was also reduced with increasing fiber loading as shown in Figure 10. As will-known, the elongation at break property mainly influenced by the ductility of the matrix phase which controls the deformation behaviour of the composites. The reduction of matrix portion or the restriction of its deformability will alter the deformation of the composite.

![Figure 10. Elongation at break of PBS/WKF composites at different fiber loading.](image)

4. Conclusion
In this study, the effect of mixing the percentage difference between PBS and WKF on the sound absorption coefficient was investigated. Based on the results, when the PBS and WKF materials were mixed with different percentages it showed that the noise absorption had decreased. Similarly, the Damping ratio test and tensile strength were found to decrease. According to the experimental data, the PBS material was better than the mixture between PBS-WKF.

5. References

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