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SOUND ABSORPTION COEFFICIENT OF NATURAL FIBRES HYBRID REINFORCED POLYESTER COMPOSITES

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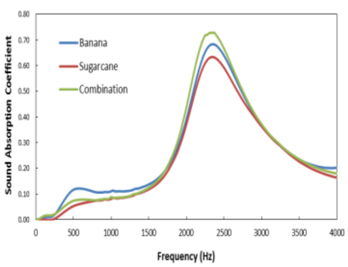
Graphical abstract



Abstract

Natural fibres have been known of its good acoustic damping properties and therefore, these materials could be used as a sound insulation in many applications. The main purpose of this investigation is to analyze the sound absorption coefficient of sugarcane baggase fibre, banana fibre and its hybrid based composites under various fibre volume fractions. Bone dry test specimens of 10%, 20% and 30% fibre volume fraction were treated with sodium hydroxide (NaOH) prior to composites fabrication using polyester as binder. The pre-tested specimens were examined using scanning electron microscope and electronic analytical balance to analyze physical and dimension characteristic. The sound absorption frequencies were measured using by the two-microphone transfer function technique in the impedance tube that has a 100 mm diameter for low frequency and 28 mm for high frequency, 0 Hz to 4000 Hz respectively. The result indicated that in low and high frequency, the combination of different natural fibres produced better sound absorption coefficient rather than using the natural fibre as individual. The results also demonstrated that the higher amounts of fibre volume fraction are affecting frequencies broadening, hence promising better sound absorbing capacity.

Keywords: Hybrid composites sugarcane baggase, banana stem, sound absorption coefficient

1.0 INTRODUCTION

Natural fibres consist of two types, namely animal fibre and plant. Several plant fibre like banana stem, coconut coir, sugarcane, kenaf are suitable to be utilized in many industrial applications. In some applications, natural fibres will replace glass fibre in reinforced polymers where fibre tensile strength is not significant because a certain stiffness. Natural fibre reinforced polymers are generally limited for use in non-structural products [1].

Noise is unwanted sound which disturbs people's work and affect people's health. Several negative effects on people's health due to noise are hearing loss, cardiovascular effects, stress, and no auditory health effect, effects of sleep, communication interference, and leads to heart disease. This research focused on sound absorption of natural fibre because natural fibre has several advantages such as renewable, cheaper, non-abrasive, abundance, and low potential health risk and safety concern during handling and processing [1].

Natural fibres have been existing for a very long time ago, which is from the beginning of the life on Earth. Many researches had been carried out regarding to the sound absorption characteristic by using natural fibre composite. Koizumi [2] found that the acoustic properties of bamboo fibre have an equivalent sound absorption with glass wool. Besides that, Yang [3] also analysed the rice straw-wood with lower specific gravity and the outcome showed it has better sound absorption at range of 1000 – 8000 Hz compared to plywood and fibreboard. Recent research was done by Fatima and Mohanty [4] where they studied the effect of treatment on jute fibre. They found that the un-treatment fibre gives better acoustic properties compared to that with treatment at frequency between 1000-4000Hz. In investigation carried out by Abdullah [5], they studied the paddy fibre in which the result showed it has a good sound absorption performance with frequency range of 2000-3500Hz with sound absorption coefficient of 0.6-0.9.

In this investigation, natural fibre which are sugarcane baggase fibre, banana fibre and its hybrid based composites are subjected to the sound absorption test. The samples are varied between 10%, 20% and 30% in order to insight the effect of fibre volume fraction dispersion towards the sound absorption coefficient performance.

2.0 EXPERIMENTAL

2.1 Materials and Fiber Preparation

The raw materials used were sugarcane baggase, banana, and polyester as the binder. The procedure to prepare sugarcane baggase fibre was begun with crushing the fibres by using crusher machine before being sundried for the duration of 1 week. Then, 5% wt sodium hydroxide (NaOH) was added into 95% wt distilled water inside a 1000 ml beaker. The solution was stirred until the entire pallet of sodium hydroxide was completely dissolved. After that, the sugarcane baggase was added into the solution. Then, the beaker was covered and stored for a few days at ambient condition. After a few days, the solution was filtered using sieve trays and the baggase was washed with water to neutralize the alkali solution. The washed baggase was then dried up in the oven for another 12 hours at 80oC temperature.

For preparation the banana fibre, the banana stem was cut into small pieces. The fiber was then cleaned by immersing it in a water tank for duration of five days at ambient condition. After that, the fiber was dried for another five days at ambient condition before being dried under sunlight for five hours.

2.2 Sample Preparation

In the fabrication stage, the sample of natural fibres was mixed with the different percentage composition of the binder. The binder used was polyester. Then, the mixtures were pressed in a mould that has a diameter of 100 mm for low frequency and 28 mm for high frequency. Polyester resin with hardener was used in this composite material and its ratio as 90:10, 80:20, and 70:30. According to Putra and co-worker [6] the composite ratio of 60:40 does not significantly affecting the performance of sound absorption.

2.2 Sound Absorption Test

The experiment was set up by using two microphones-transfer function method was undertaken in accordance with ASTM E1050-98 as shown in Figure 1. The calibration of two microphones was performed with a noise generator from a loud speaker. The function is to incidence acoustic absorption an indicator frequency value set for 0 to 1 (most critical property in sound absorption coefficient). Sound waves are translated into digital signal using the user-friendly software (SCS 80FA) and save the output result

Figure 1 The impendence tube

3.0 RESULTS AND DISCUSSION

3.1 Physical Evaluations

Table 1 shows the fibre diameter, porosity and density of the each natural fiber. There are varieties sizes of fibers, the averages diameter is calculated. The SEM micrograpgh of the speciemens can be seen in Figure 2, Figure 3 and Figure 4. Combination of banana stem fiber and sugarcane fiber has a lower diameter of fiber size which is 14.63 μm. However, the sugarcane baggase fiber has a highest diameter of fiber which is 18.05μm compared with banana stem fiber has are 15.61μm of diameter.

Porosity is the one of the factors that must be considerably change the acoustic impedance and absorption coefficient of the acoustic absorber. Sugarcane baggase fiber at 20% has the highest porosity while the combination of both fibres at 30% has the low porosity. According to the porosity equation, the increase in bulk density reduce the porosity for example, perforation less exist that increase the coefficient of sample absorption and peak resonance frequency is lower [7].

Density is the quantity of mass per unit volume of a substance. Solid density also can be obtained by weight of the sample in the air, weight in liquid and the density of the liquid. The combination of baggase and banana stem fibre at composite ratio of 10% has the highest density with 1.513 g/cm^3. Besides, the combination of both fibres at 30% has the lowest density with 1.107 g/cm^3. The higher the cellulose content is directly proportion the cell wall density because the density of natural fiber is governed by their cellulose cell wall density.

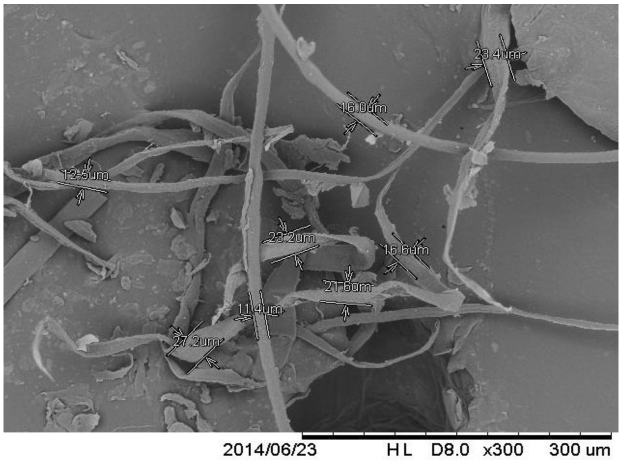


Figure 2 Banana stem fiber

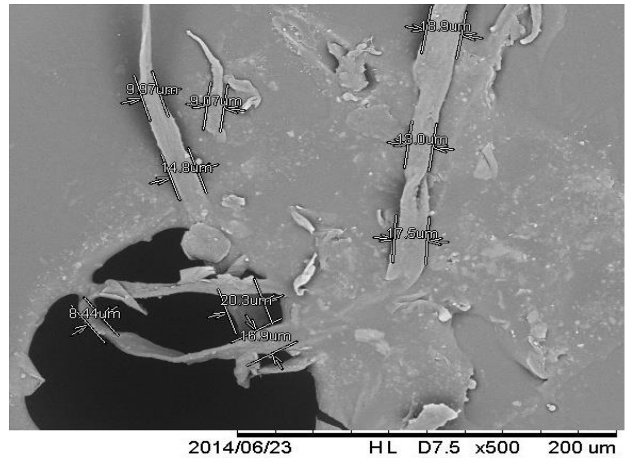


Figure 3 Sugarcane baggase fiber

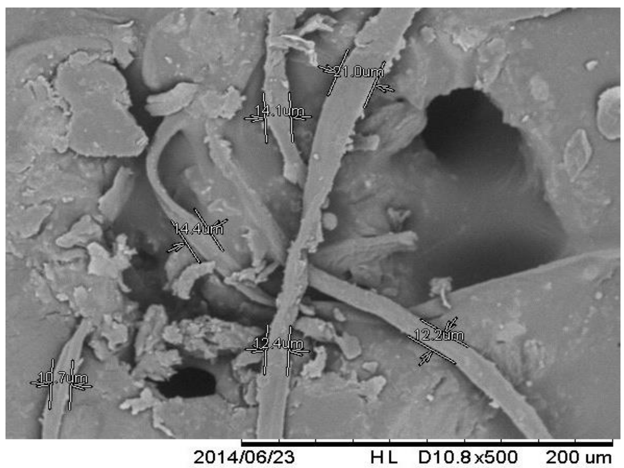


Figure 4 Combination of banana stem and sugarcane baggase fiber

Table 1 Physical attributes of composites, Fibre diameter, porosity and density

Fibre	Composite Ratio (%)	Diameter of Fibre (μm)	Porosity (%)	Density (g/cm³)
Sugarcane	10	15.61	0.132	1.351
	20		0.134	1.472
	30		0.110	1.225
Banana Stem	10	18.05	0.119	1.164
	20		0.116	1.261
	30		0.090	1.189
Sugarcane + Banana stem	10	14.63	0.132	1.513
	20		0.114	1.405
	30		0.090	1.006

3.2 Sound Absorption Coefficient

Figure 5 shows the graph of sound absorption coefficient of banana stem fibre, sugarcane fibre and the combination of banana stem and sugarcane fiber at the low and high frequency. The composite ratio of the specimen is a 10% fibre and 90% polyester. It can clearly be seen that the combination of fibre is a good sound absorption coefficient with 0.7331 at 2325Hz. Meanwhile sound absorption coefficient of the sugarcane fiber is much lower of 0.6338 at 2350Hz. On the other hand, the sound absorption coefficient of banana fibre is 0.6835 at 2350Hz. At lower fibre volume it can be noticed that, all the curves peaked at within the same frequency. This suggests either the fibers or its combination could absorb specific certain frequency domain.

Figure 6 shows the graph of composite ratio of 20% fibre and 80% polyester explains that the combination of both the fibres is higher sound absorption coefficient with 0.7306 at 2500Hz. Meanwhile, the sugarcane fibre has better sound absorber compared to the banana fiber with sound absorption coefficient is 0.7122 at 2275Hz and the banana fibre at 2775Hz with 0.5865 of sound absorption coefficients. Unlike Figure 5, the effect of fibre volume fraction could indicate something meaningful. While sugarcane fiber and its combination peaked at lower frequency, the Banana fiber is likely the highest in the coefficient evaluation but the curves was much more broadening by taking area under the curve. This suggests Banana fiber could offer better sound absorption coefficient on larger scales of frequency.

Figure 7 shows graph of sound absorption coefficient of 30% fibre and 70% polyester also illustrate the combination of fibre is excellent sound absorption with the absorption coefficient is 0.7332 at 3100Hz. Besides that, the sugarcane fibre has absorption coefficient at 3050Hz with 0.6314. Last but not least, the sound absorption coefficient of banana fibre is 0.6998 at 2650Hz. In term of frequency domain, the curves are much broadening compared to Figure 5 and Figure 6. This indicates the higher amount of fiber, more frequencies can be absorbed by the natural fibres and its hybrid composite.

Figure 8 shows the highest sound absorption coefficient performance according to the composite ratio of combination of banana stem and sugarcane baggase fibre. In this result, the sound absorption coefficient is slightly increased and dramatic decline except for 20% of combination fibre. The 20% combination fibres are raising then reduces at 2550Hz. However at frequency 3950Hz the absorption coefficient is increased back till 4950Hz with absorption coefficient is 0.7254. From the graph of the composite ratio above, the highest and the good sound absorption is on 30% fibre and 70% polyester with 0.7332 of sound absorption coefficient at 3100Hz. As can we see at 0- 1000Hz, the frequency of sound absorption is low. On the other hand, the effect of varying can be confirmed. While sound absorption coefficient remained the same, the peaks shifted from lower to higher frequency as the fibre volume fraction improves. This suggest adding more fibres might not be significant in getting better sound absorption coefficient but rather to tackle or absorbing any desired specific frequency. To improve the sound absorption are with adding air spaces behind the tested composite system [8]. In addition, increasing the thickness of the specimen is a way to improve the sound absorption at low and high frequency because frictional loses increased thus the sound energy damped [8]. Furthermore, when decreasing the fibre diameter will influence the noise coefficient [9].

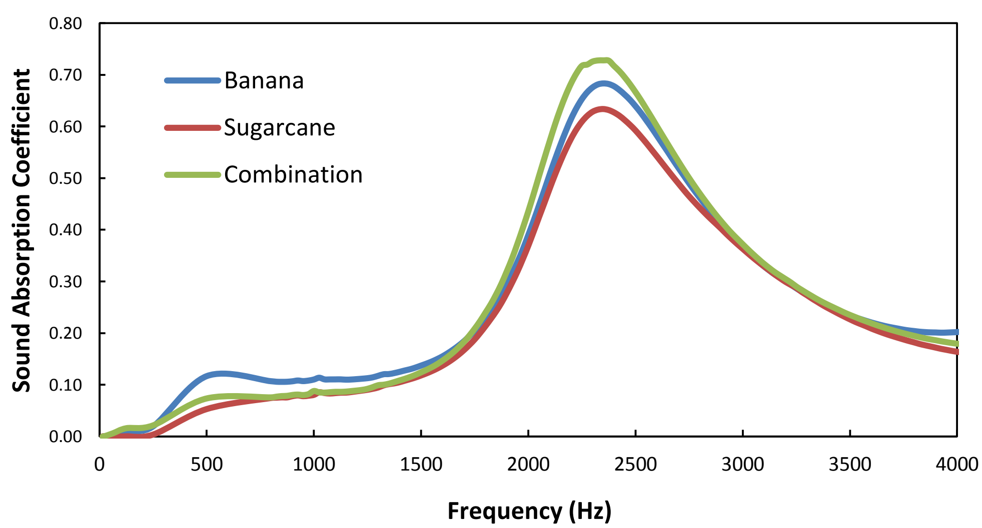


Figure 5 Sound absorption coefficient versus frequency of 10% fibre/80% polyester

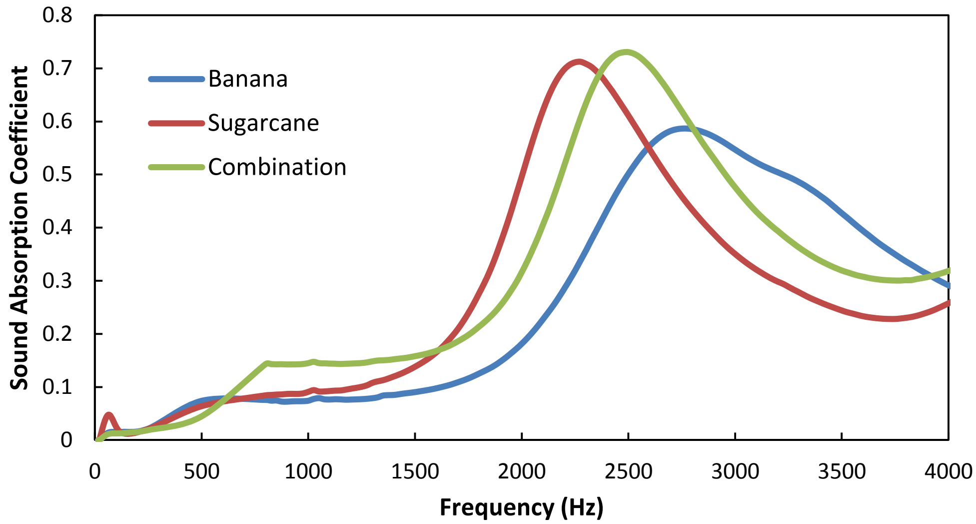


Figure 6 Sound absorption coefficient versus frequency of 20% fibre/80% polyester

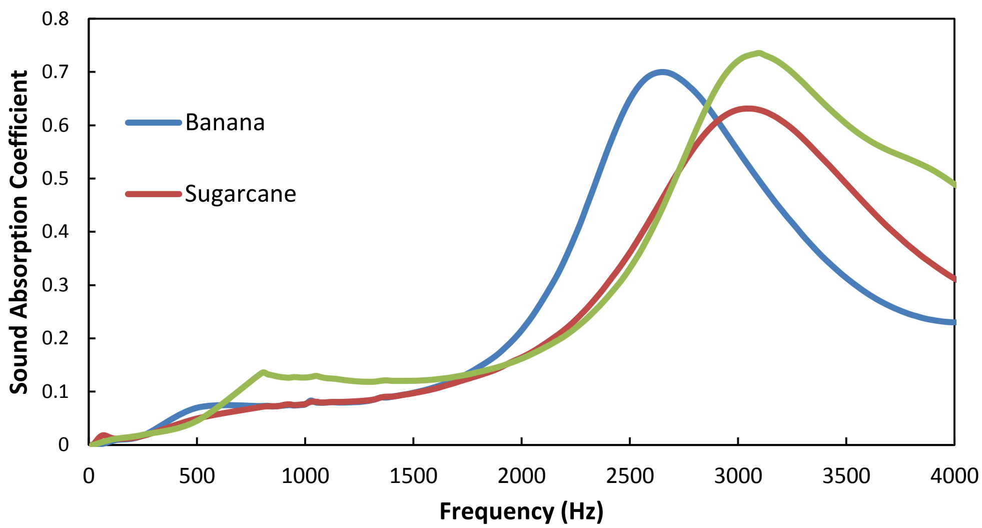


Figure 7 Sound absorption coefficient versus frequency of 80% polyester and (c) 30% fibre/70% polyester

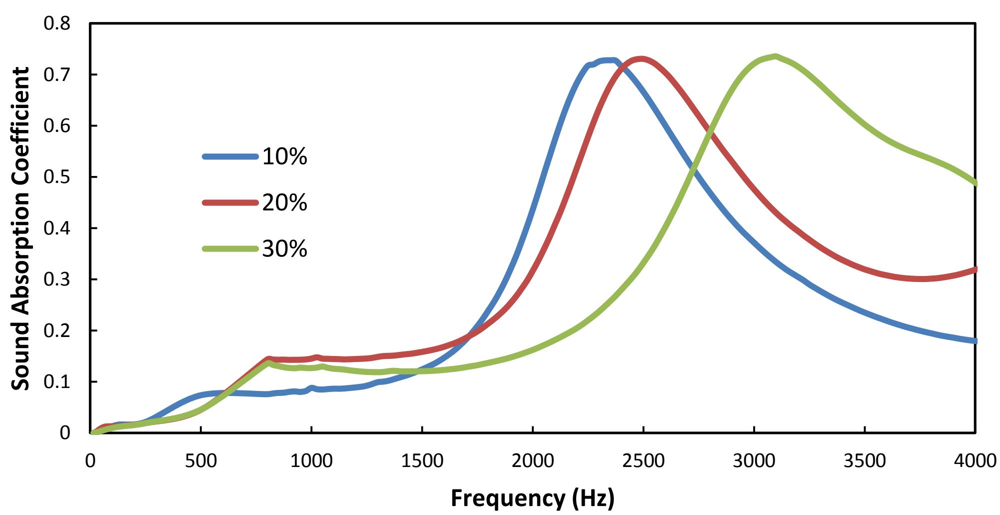


Figure 8 Sound absorption coefficient versus frequency of the highest sound absorption performance according to the composite ratio

4.0 CONCLUSION

In summary, the porosity is highest in the combination of 10% fibre with 0.132% and lowest at 30% of combination which is 0.09%. In addition, the sample of combination of both fibres at 30% show the density of 1.006 g/cm^3 which is the lowest among the other sample while the 10% of combination is the highest density. The combination of the sugarcane baggase and banana stem with use polyester as binder proved that the combination of both fibres is the good sound absorption at the low and high frequency. The 30% fibre and 70% polyester are the highest sound absorption coefficient with 0.7332 at 3100 Hz. Besides that, with decrease the diameter size of fiber also can increase the sound absorption coefficient.

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