

# Mathematical modeling on sound absorption of oil palm empty fruit bunch fibers

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**ABSTRACT** – Oil Palm Empty Fruit Bunch (OPEFB) fibers is an agricultural waste which is available in abundance quantity in Malaysia. This paper discusses the analytical approach used to estimate the sound absorption curve of Oil Palm Empty Fruit Bunch (OPEFB) fibers. Experimental measurement is done by using impedance tube testing to obtain the sound absorption coefficient. The results from the experimental works are validated by comparing with Delany-Bazley model. It is found that the Delany-Bazley model can be used to predict the sound absorption coefficient of OPEFB fibers.

## 1. INTRODUCTION

The application of ‘green’ material as acoustic absorber is developing due to its benefits over synthetic materials which are harmful to environment and human’s health. Putra et al. employed hollow structure which is bamboo as sound absorber. Addition of fabric at the front surface of bamboo and application of air gap improved absorption at lower frequency region [1]. Researches done by Lim et al. and Or et al. on kenaf fiber sheet and oil palm empty fruit bunch fibers respectively show that increase of thickness and application of air gap improved the peak of absorption coefficient curve and widen the frequency bandwidth of absorption [2,3]. Fouladi et al. analysed the acoustical properties of coir fiber by using two analytical models, namely Delany-Bazley and Biot-Allard [4]. They found out that Delany-Bazley model is easy to use compared to Biot-Allard model. This will be beneficial for the application of fibers in the industry. This paper discusses the application of analytical model, i.e. Delany-Bazley to estimate the sound absorption performance of OPEFB fibers from the experimental works which according to the author’s knowledge has not been investigated by other researchers.

## 2. METHODOLOGY

Samples of OPEFB fibers were fabricated by using hot compression technique without using any binder. The samples were designed based on different densities but same thickness and same density but different thicknesses.

The data on experimental measurement was

obtained from the 2-microphones impedance tube testing according to ISO 10534-2 [5].

For the analytical approach, Delany-Bazley model was studied to predict the sound absorption coefficient curve of OPEFB fibers [4,6].

The characteristic impedance  $Z_o$  and propagation constant  $\gamma$  of a layer of homogeneous porous material are shown in Equation (1) and Equation (2) [4]. The  $Z_o$  and  $\gamma$  are depend on the frequency of the analysis and flow resistivity of the porous material, i.e. OPEFB fibers.

$$Z_o = \rho_o c_o \left\{ \left[ 1 + c_1 \left( \frac{f \rho_o}{\sigma} \right)^{c_2} \right] - i \left[ c_3 \left( \frac{f \rho_o}{\sigma} \right)^{c_4} \right] \right\} \quad (1)$$

$$\gamma = k_o \left\{ c_5 \left( \frac{f \rho_o}{\sigma} \right)^{c_6} + i \left[ 1 + c_7 \left( \frac{f \rho_o}{\sigma} \right)^{c_8} \right] \right\} \quad (2)$$

where  $\rho_o$  is density of air,  $c_o$  is speed of sound,  $c_1 - c_8$  is Delany-Bazley regression constants [6],  $f$  is frequency of sound,  $\sigma$  is flow resistivity and  $k_o = 2\pi f / c_o$  is wave number of air.

The surface acoustic impedance  $Z$  of a rigidly-backed material of thickness  $t$  is shown in Equation (3) [6].

$$Z = Z_o \coth \gamma t \quad (3)$$

The normal incidence sound absorption coefficient of OPEFB fibers based on Delany-Bazley model is derived from Equation (3) and is shown in Equation (4) [6].

$$\alpha = 1 - \left| \frac{Z - \rho_o c_o}{Z + \rho_o c_o} \right|^2 \quad (4)$$

## 3. RESULTS AND DISCUSSION

Figure 1 shows the graph of sound absorption coefficient versus frequency of OPEFB fibers with different densities but having the same thickness, i.e. 20 mm. From the figure, the Delany-Bazley model can predict the behaviour of the curves with minor deviation from the experimental work.

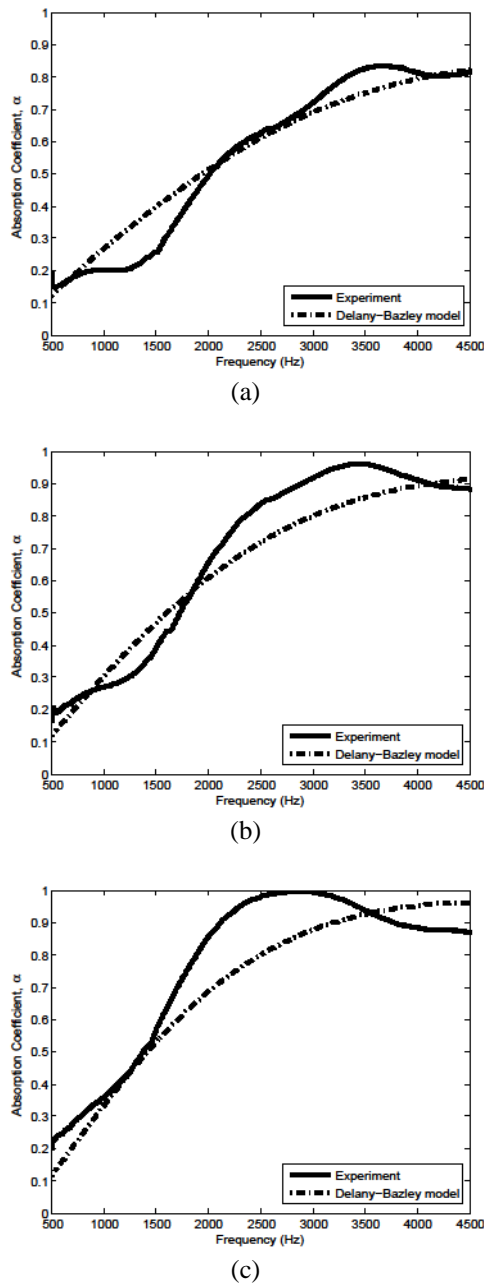


Figure 1 Graph of sound absorption coefficient versus frequency of OPEFB fibers with 20 mm thick and density of (a) 175.4 kg/m<sup>3</sup>, (b) 233.8 kg/m<sup>3</sup> and (c) 292.3 kg/m<sup>3</sup>.

Figure 2 shows the graph of sound absorption coefficient versus frequency of OPEFB fibers with the same density as Figure 1(c), which is 292.3 kg/m<sup>3</sup> but having thicker sample, i.e. 50 mm. From Figure 2, the Delany-Bazley model can roughly estimate the pattern of the sound absorption coefficient curve. However, this analytical model cannot predict the dips of the curve at 1.5 to 2.3 kHz and 3.8 to 4.5 kHz. This is due to Delany-Bazley model considered the porous layer as bulk material. Thus, in this model, physical characteristic such as flow resistivity alone is considered to predict the sound absorption coefficient of the porous material.

Apart from poor prediction of sound absorption coefficient at the dip of the curve, the Delany-Bazley model is still useful to predict the behaviour of the

sound absorption performance of OPEFB fibers due to its simplicity in application.

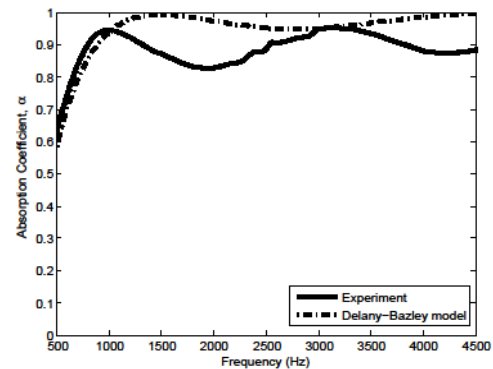


Figure 2 Graph of sound absorption coefficient versus frequency of OPEFB fibers with density of 292.3 kg/m<sup>3</sup> and 50 mm thick.

#### 4. CONCLUSION

The Delany-Bazley model is found to be simple model which is easy to apply and can well-predict the sound absorption coefficient curve for 20 mm thick sample with different densities. Minor deviation between the Delany-Bazley model and the experimental measurement is observed for all the samples. However, the dips of the curve from the experimental measurement for thicker sample are poorly estimated. The study of other analytical models is thus of interest to improve the prediction on the peaks and the dips of the sound absorption coefficient curve.

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#### REFERENCES

- [1] A. Putra, F.B.A. Khair, and M.J.M. Nor, "Utilizing Hollow-Structured Bamboo as Natural Sound Absorber," *Archives of Acoustics*, vol. 40, no. 4, pp. 601-608, 2015.
- [2] Z.Y. Lim, A. Putra, M.J.M. Nor, and M.Y. Yaakob, "Preliminary study on sound absorption of natural kenaf fiber," in *Proceedings of Mechanical Engineering Research Day 2015*, 2015, pp. 95-96.
- [3] K.H. Or, A. Putra, and M.Z. Selamat, "Oil palm empty fruit bunch fibers as sustainable acoustic material," in *Proceedings of Mechanical Engineering Research Day 2015*, 2015, pp. 99-100.
- [4] M.H. Fouladi, M. Ayub, and M.J.M. Nor, "Analysis of coir fiber acoustical characteristics," *Applied Acoustics*, vol. 72, no. 1, pp. 35-42, 2011.
- [5] Acoustics - Determination of sound absorption coefficient and impedance in impedance tubes - Part 2: Transfer-function method, ISO 10534-2, 2001.
- [6] M.E. Delany, and E.N. Bazley, "Acoustical properties of fibrous absorbent materials," *Applied Acoustics*, vol. 3, no. 2, pp. 105-116, 1970.