

24th COBEM - 2017



24th ABCM International Congress of Mechanical Engineering
December 3-8, 2017, Curitiba, PR, Brazil

COBEM 2017 - 2063

FLOW RESISTIVITY, CHARACTERISTIC IMPEDANCE AND COMPLEX WAVE NUMBER ASSESSMENT OF COCONUT FIBRE WITH THIN THICKNESS SAMPLES

Nelson Luís Maurios Legat Filho

Key Fonseca de Lima

Nilson Barbieri

Fernando Jun Hattori Terashima

Vinicius Antônio Grossl

Pontifícia Universidade Católica do Paraná, Rua Imaculada Conceição, 1155, Curitiba, Paraná, Brazil.

nelson.legat@pucpr.br

key.lima@pucpr.br

nilson.barbieri@pucpr.br

fernando.jun@pucpr.br

vinicius.antonio@pucpr.br

***Abstract.** In this article, characteristic impedance and complex wave number for the coconut fiber have been evaluated for samples with 5 and 10 mm thicknesses at low frequencies. These properties were obtained applying the classical empirical equations of Delany and Bazley (1970). In addition, these equations need the flow resistivity assessment of the fiber samples, which is followed by the standard ASTM C522-03 (2010). As a result, the flow resistivity values are different for two thicknesses measured, but the impedance and complex wave number obtained are similar.*

***Keyword:** flow resistivity, characteristic impedance, complex wave number, coconut, fiber*

1. INTRODUCTION

Sustainable materials are more often requested nowadays in acoustic applications, since the synthetic materials are generally toxic when burned and unviable for discard on the environment, researches are growing on this kind of materials which got good potential for acoustic uses.

Currently, Brazil have a fleet with more than 40 million automotive vehicles circulating (ANFAVEA, 2016) and the most part of this vehicles are concentrated in the big cities, in that case, natural materials are being developed to minimize the noise pollution, and coconut fiber is one of them and it was chosen in this work. The husk of the coconut fiber are agricultural wastes and they have been used in many new industries applications, such as acoustic filters, vehicle roof trim, structural materials and thermal isolation.

The purpose of this paper is to evaluate the impedance and complex wave number of the coconut fiber through the flow resistivity method following the standard ASTM C522-03 (2010). These properties are obtained by applying the classical empirical equations of Delany and Bazley (1970).

2. METHOD DESCRIPTION

Flow resistivity is defined by the boundary layer of the fluid, which directs through the interstice of the analyzed material, which makes the material create a fluid resistance due the viscosity, as known as dissipation. (GIESBRECHT, 2017).

This method it is very important to evaluate other properties, like absorption coefficient, of the absorbent porous materials and it is used to compare with others experimental methods of material characterization in literature, for example, the two thickness method by Ferrero and Sacerdote (1951) or the two cavity method by Utsuno *et al* (1989).

The flow resistivity (r_0) of the specimens may be evaluated experimentally by measuring the quotient of the difference pressure (Δp) between the samples by the product of the air velocity of the steady flow through the tube (u) and the sample thickness (t), given by equation 1:

$$r_0 = \frac{\Delta p}{u \cdot t} \text{ [rayl/m]} \quad (1)$$

Also, by definition, the flow resistance is the quotient of the difference pressure by the airflow velocity, and is expressed by:

$$r = \frac{\Delta p}{u} \text{ [rayl]} \quad (2)$$

The values of the flow resistance must be between 100 to 100.000 mks rayls and the airflow velocities between 0.5 to 50 mm/s, if the experiment don't reach none of these values and the samples analyzed are thin, it is necessary to combine more than one specimen together and re-measure.

Once know the r_0 value, the characteristic impedance and the complex wave number are calculated respectively by Delany and Bazley's empirical equations 3 and 4.

$$\frac{\tilde{z}}{z_0} = \left[1 + 0,0511 \left(\frac{f}{r_0} \right)^{-0,75} \right] - i \left[0,0768 \left(\frac{f}{r_0} \right)^{-0,73} \right] \quad (3)$$

$$\frac{\tilde{k}}{k_0} = \left[1 + 0,0858 \left(\frac{f}{r_0} \right)^{-0,70} \right] - i \left[0,1749 \left(\frac{f}{r_0} \right)^{-0,59} \right] \quad (4)$$

Where f is the excitation frequency, k_0 and z_0 are the wave number and impedance of the air, respectively and i is the imaginary number.

3. EXPERIMENTAL PROCEDURE

The procedure consist on an air source, with constant flow rate, flow meter, pressure reducing valve and particle filter, pressure differential manometer, multimeter, DC (direct current) source, tube and sample holder on an acrylic tube. The assembly of the equipment is represented by Figure 1.

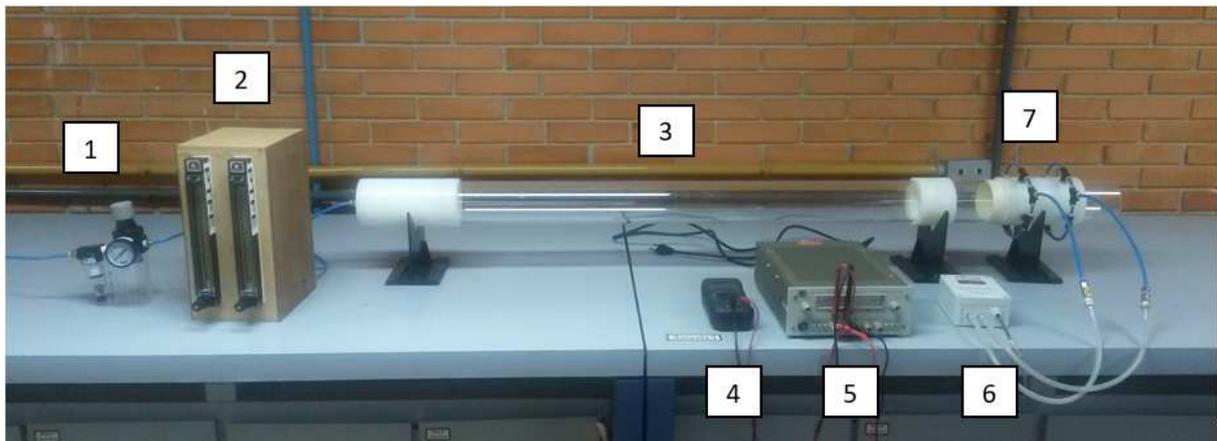


Figure 1: (1) pressure reducing valve and particle filter, (2) flow meter, (3) acrylic tube, (4) multimeter, (5) DC source, (6) pressure differential manometer (Full scale = 60 Pa), (7) sample holder.

The pressure difference is obtained when the flow before and after of the samples are evaluated by the difference pressure manometer for each airflow velocity. The coconut samples analyzed have 62 mm of diameter and the length of the tube is 1100 mm, sufficiently enough for laminar flow, according to Fox *et al.*, 2006, expression, given by equation 5.

$$\frac{L_e}{d} \approx 0,06Re \quad (5)$$

Where L_e is the tube length, d is the diameter and Re is the Reynolds number.

4. RESULTS AND DISCUSSION

In this topic, flow resistivity and acoustic properties of the coconut fiber are shown. Six samples of 5 mm and four samples of 10 mm were put together for each measurement. The Figure 2 shows the values of the flow resistivity for each velocity for the samples of coconut fiber with 5 and 10 mm thickness. The red dots shows the mean values of the flow resistivity, black lines shows the standard deviation and the blue lines shows the linear fits. Thus, the mean values of flow resistivity are represented on Table 1, as the density and thickness, respectively.

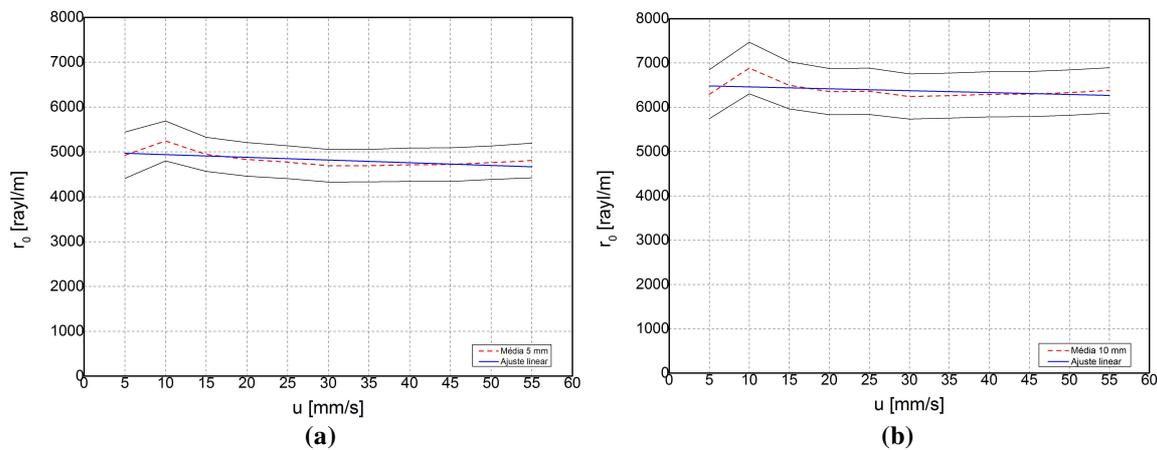


Figure 2 – (a) Flow resistivity of coconut fiber with 5mm thickness, (b) Flow resistivity of coconut fiber with 10 mm thickness

Table 1. Coconut fiber properties.

	r_0 [rayl/m]	ρ [kg/m ³]	t [mm]
<i>Coconut 5mm</i>	<i>4827</i>	<i>192</i>	<i>5.42</i>
<i>Coconut 10mm</i>	<i>6381</i>	<i>209</i>	<i>10.10</i>

It is notable on Figure 2, between 0 and 15 mm/s flow velocities, that the values of the resistivity are not constant, this is due to the low flow resistance values below the by the ASTM C522-03 (2010) norm. Above 15 mm/s the results are satisfactory for both thicknesses.

Hence, the normalized characteristic impedance and complex wave number of the coconut fiber for both thickness, are calculated with equations 3 and 4 and Table 1 values, showed in Figure 3, respectively.

Figure 3 shows that the characteristic impedance and complex wave number for specimens of coconut fiber with 5 and 10 mm are very similar, even though, the difference of 1500 rayls approximately, doesn't modify significantly the results of the characteristic impedance and complex wave number. This was verified by TERASHIMA (2016), the author measured samples of coconut fiber and polyurethane, and the flow resistivity of the polyurethane are much higher than the value of the coconut fiber, the results implied on a significantly difference of characteristic impedance and complex wave number using Delany and Bazley's equation.

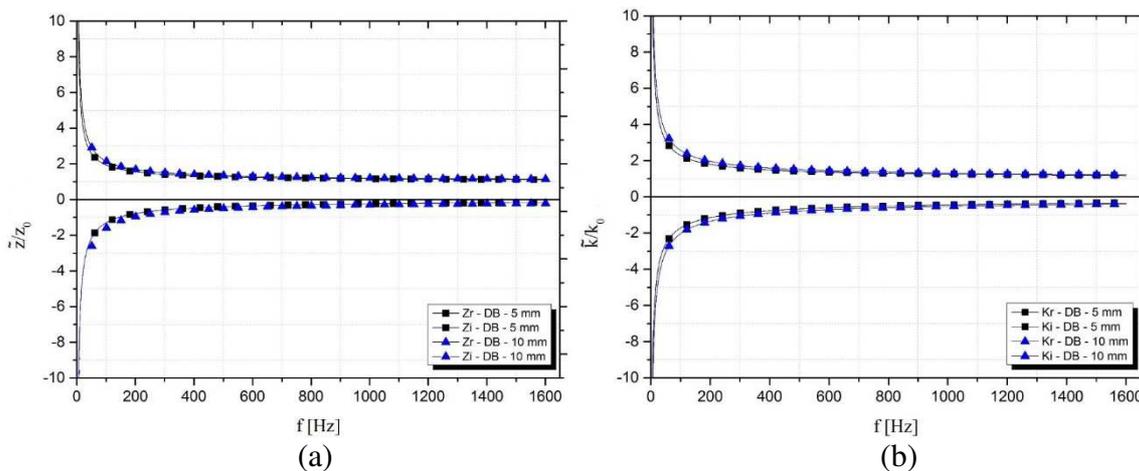


Figure 3 – (a) Normalized characteristic impedance of coconut fiber, (b) Normalized complex wave number of coconut fiber

5. CONCLUSIONS

Coconut samples are difficult to obtain a precise thickness as showed on Table 1, the fibers are not constant along its length and the process to make samples are handmade, hence, all the samples are different each from other, consequently on this work, ten samples were made and measured for each thickness. Nevertheless the values of the density and the thickness were tolerable.

The flow resistivity is proportional with the sample thickness, however the values on Table 1 do not show that proportion, due the fact that for samples of 5 mm thickness were combined six samples totalizing 30 mm of thickness and for the samples with 10 mm, were combine four samples, totalizing 40 mm thickness, however, the airflow resistance value is constant. As the thickness of the samples increases, consequently the flow resistivity increases as well, though the values of flow resistivity between 5 and 10 mm thickness, are nearly the same, as a result, the impedance and the wave number showed in the Figure 3 are similar. In addition, it is necessary another method to verify the characteristic impedance and complex wave number, for example, the impedance tube methods, considering that there is a difference between the flow resistivity values.

6. ACKNOWLEDGMENTS

This work was financial supported by CAPES.

7. REFERENCES

- ANFAVEA, 2016. “Anuário da Indústria Automobilística Brasileira”.
- ASTM C522-03, 2010. “Standard Test Method for Airflow Resistance of Acoustical Materials”.
- ASTM E2611-09, 2009. “Standard test method for measurement of normal incidence sound transmission of acoustical materials based on the transfer matrix method”.
- Delany, M. E., Bazley, E. N., 1970. “Acoustical properties of fibrous absorbent materials”, *Applied Acoustics* 3, pp. 105-116.
- Ferrero, M. A., Sacerdote, G. G., 1951. “Parameters of sound propagation in granular absorption materials”, *Acoustic* 1, vol. 1, pp. 135-142.
- Giesbrecht, P.K., 2007. “Incerteza na Medição das Características Acústicas dos Materiais”, (Dissertação), Universidade Federal de Santa Catarina, pp. 9-12.
- Lima, K. F., Barbieri, N., Barbieri, R., Grossl, V. A., 2016. “Determination of the acoustical properties of sisal and coconut fiber samples based on the flow resistivity experimental assessment”. *The Journal of the Acoustical Society of America*, v. 140, p. 3141-3141.
- Terashima, F., J., 2016. “Caracterização das Propriedades acústicas de materiais absorventes de pequenas espessuras com três métodos de avaliação”, *Dissertação*, Pontifícia Universidade Católica do Paraná, Paraná.
- Utsuno, H., Tanaka, T., Fujikawa, T., Seybert A. F., 1989. “Transfer function method for measuring characteristic impedance and propagation constant of porous material”, *Journal of the Acoustical Society of America*, vol. 86, pp. 637-643.

8. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.