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PROPOSAL A EMPIRICAL MODEL FOR ABSORBENT ACOUSTICAL MATERIALS BASED IN KENAF

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ABSTRACT

Nowadays, in the market there exists a different absorbent acoustical material. There are accepted models from the scientific community about mineral wool, glass wool, rock wool, foam or polyester fibre. Several of these models are empirical. They are obtained from the equation adjustments about the acoustic impedance and propagation constant behaviour, depending upon the flow resistivity, fibre's diameter and density. There are even standars like UNE-EN 12354-6 where these models are accepted under certain limitations like the fundamental basis as in the materials' acoustics behaviour prediction. This work presents a complete study about a new absorbent acoustical material whose development is based in natural fibre. This fibre is obtained from a plant and this plant is named Kenaf. Investigations from different tests in the laboratory are proposed showing empirical equations about this new material's acoustical behaviour.

INTRODUCTION

The bio-material fibre known as kenaf is an innovative alternative in the acoustic world. For this fibre material no specific model exists, and the existing models don't reproduce satisfactorily the experimental results. This leads us to review the already existing models in order to provide new coefficients that describe the acoustic behaviour of this material. Therefore, the main goal of the present work is the development of a new mathematical model of flow resistivity, acoustic impedance and the sound absorption coefficient of kenaf fibre material and the verification of its reliability.

CHARACTERISTICS OF KENAF

This material has advantages over the other materials used now, both for the environment and health and safety at work. First, kenaf's fibres are obtained from the stem of the kenaf plant. The rest of the plant (flowers and leaves) is totally usable for other end purposes like oils, food for animals, etc. In addition, during the process of the final material it is not necessary to utilise any type of toxic resin thanks to the thermos - merger (140 º-150ºC) of the kenaf fibres . These fibres remain linked together thanks to the mixing of any polyester fibres. Moreover, the diameter of the kenaf fibre is superior to the diameter of the skin pore. Working with this material is safe (no need for health and safety equipment) thereby giving quick results. For this work the samples used have been thicknesses between 1.5 and $4\,cm$ and densities between 60 and 125 kg/m^3

DESCRIPTION SEMI-EMPIRICAL MODEL

Now, in the scientific world, three kinds of mathematical models can be found: semi-empirical, phenomenological and micro- structural models. This work presents a model about a new absorbent acoustical material whose development is based in natural fibre. This fibre is obtained from a plant and this plant is named Kenaf. This model has achieved the absorption coefficient, according to a few measurable physical parameters. Thus we have in the equation the smallest possible margin of error.

The key parameter in this method is the airflow resistivity. This parameter has been obtained in the laboratory using the Ingard&Dear[1] method. This method describes an alternative to the standard UNE-EN 29053[2].

Figure 1-Mesured of the airflow resistivity in laboratory, Ingard&Dear method.

The airflow resistivity was measured using the transfer-function method in an impedance tube [1]. There are frequencies where the imaginary part of the airflow resistivity (reactance) is void. This allows us to obtain the desired airflow resistivity values, easily and satisfactorily. With these values fitting the proposed equations for Delany-Bazley[3] and with the absorption coefficient's values (measured in the laboratory), we can obtain the semi-empirical values of this new material's acoustical behaviour.

The predicting model for sound absorption coefficient (at normal incident) has been derived from the Delany-Bazley model [3], and used as optimised for different materials by other authors [4]:

$$\alpha = \left(\frac{2\times\pi\times f}{c_0}\right)\times\left[C_5\times\left(\frac{\rho_0\times f}{r}\right)^{-C_6}\right] \quad \text{(Eq.1)}$$

$$\beta = \left(\frac{2\times\pi\times f}{c_0}\right)\times\left[1+C_7\times\left(\frac{\rho_0\times f}{r}\right)^{-C_8}\right] \quad \text{(Eq.2)}$$

$$Z_R = \rho_0\times c_0\left[1+C_1\times\left(\frac{\rho_0\times f}{r}\right)^{-C_2}\right] \quad \text{(Eq.3)}$$

$$Z_I = -\rho_0\times c_0\left[C_3\times\left(\frac{\rho_0\times f}{r}\right)^{-C_4}\right] \quad \text{(Eq.4)}$$

Where α and β are the real and imaginary parts of the propagation constant, Z_R and Z_I are ther real and imaginary parts of the specific acoustic impedance, r is the airflow resistivity

$\left(N \times s/m^4\right)$ f is the frequency (Hz), ρ_0 is the air density ($\approx$1'2kg/m^3) and c_0 is the sound velocity in the air ($\approx$343 m/s).

We have used the eight coefficients (C_1-C_8) described in [3] as input values, and by search and mistakes limitation, we have obtained the coefficients that adjust satisfactorily to the experimental values of the sound absorption coefficient (at normal incident).Below, the equations show the method for obtaining the sound absorption coefficient through the propagation constant and the specific acoustic impedance :

$$Z_l = (Z_R + j \times Z_I) \times [\coth(\alpha + j \times \beta) \times l] \quad \text{(Eq.5)}$$

$$\alpha_n = \frac{4 \cdot Z_{lR} \cdot \rho_0 \cdot c_0}{|Z_l| + 2 \cdot \rho_0 \cdot c_0 \cdot Z_{lR} + (\rho_0 \cdot c_0)^2} \quad \text{(Eq.6)}$$

l is samples' thickness, en m.

RESULTS

Table I shows the values of the eight coefficients proposed by different authors (by different materials) and the values obtained for the kenaf.

Table II shows the mean deviation between the measured values of the sound absorption coefficient and the calculated values using Delany-Bazley method, Pompoli-Garai method and kenaf method.

Table I. Values of the eight coefficients of the new model, kenaf model, campared with values found by Delany-Bazley and Pompoli-Garai.

Modelos	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
Delany-Bazley	0.057	0.754	0.087	0.732	0.189	0.595	0.098	0.700
Pompoli-Garai	0.078	0.623	0.074	0.660	0.159	0.571	0.121	0.530
Kenaf	0.046	0.255	0.112	0.967	0.060	1.256	0.039	0.541

Tabla 2. Mean deviation between the measured values of the sound absorption coefficient and the calculated values using, kenaf model, Delany-Bazley , Pompoli-Garai models.

Model	Mean deviation of sound absorption coefficient
Delany-Bazley	0.0987
Pompoli-Garai	0.0907
Kenaf	0.0563

Frequency's limits of the model

The propagation constant and the specific acoustic impedance described in [3], equations 1-2 and 3-4, are based in interpolations of measures to f/r. The valid rank for these relations is the following one:

$$10^{-2} \leq f/r \leq 1 \qquad \text{(Eq.7)}$$

For values outside this rank, these equations are not applicable.

For the results shows in this wok, we have analysed different kenaf's samples. In the laboratory of the Higher Polytechnic School of Gandía, Polytechnic University of Valencia, we have measured the airflow resistivity (Ingard-Dear) and the sound absorption coefficient (UNE-EN ISO 10534-2).In figures 2, 3 and 4, measured values and predicted values are compared. Figures 2 and 3 shows this results for samples the 70 kg/m^{3}, 73 y 28 mm, respectively. Figure 4 shows the kenaf's sample with 60 kg/m^3 and 42mm, and figure 5 shows kenaf's sample with 65 kg/m^3 and 68mm.

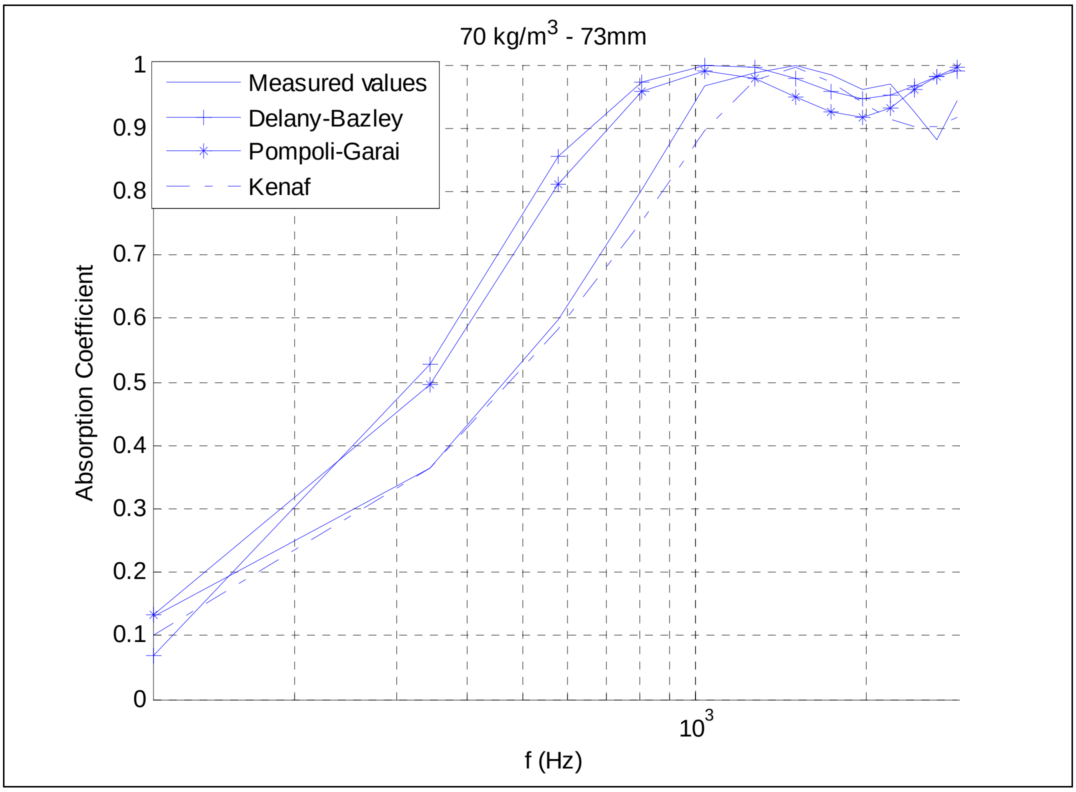

Figure 2- Sound absorption values at normal incidence: comparison between measured values and calculated values.

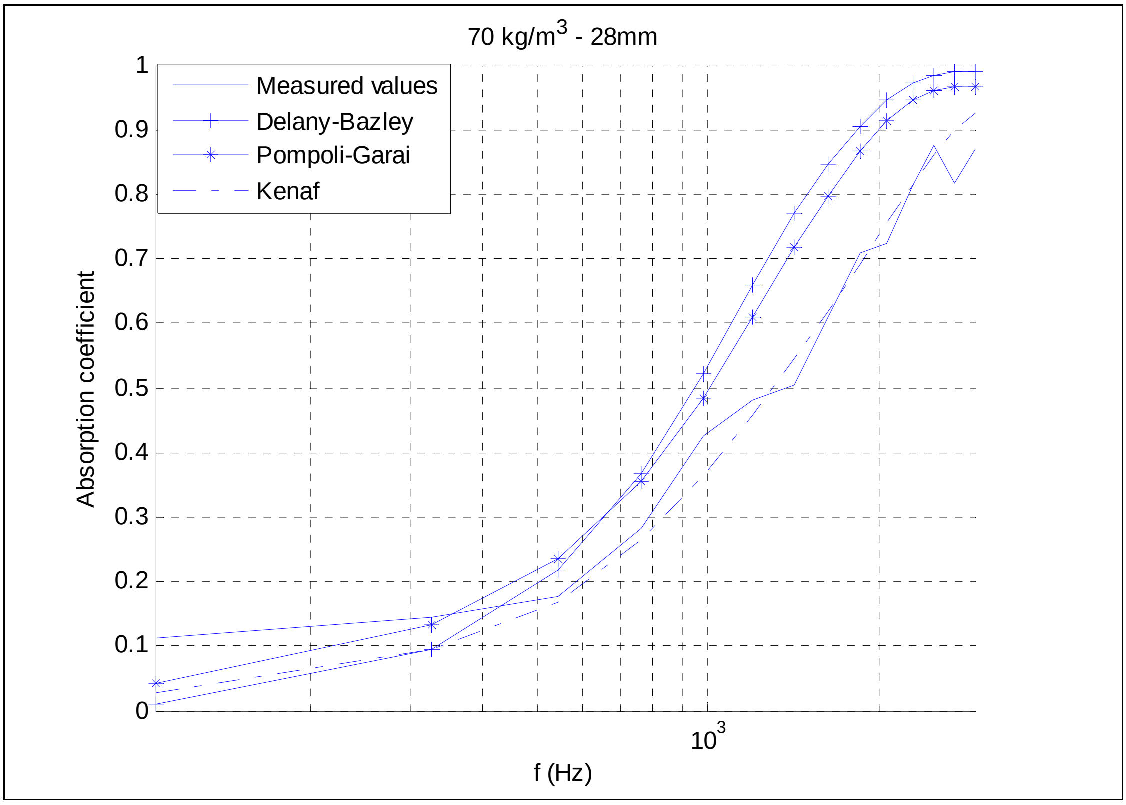

Figure 3 - Sound absorption values at normal incidence: comparison between measured values and calculated values.

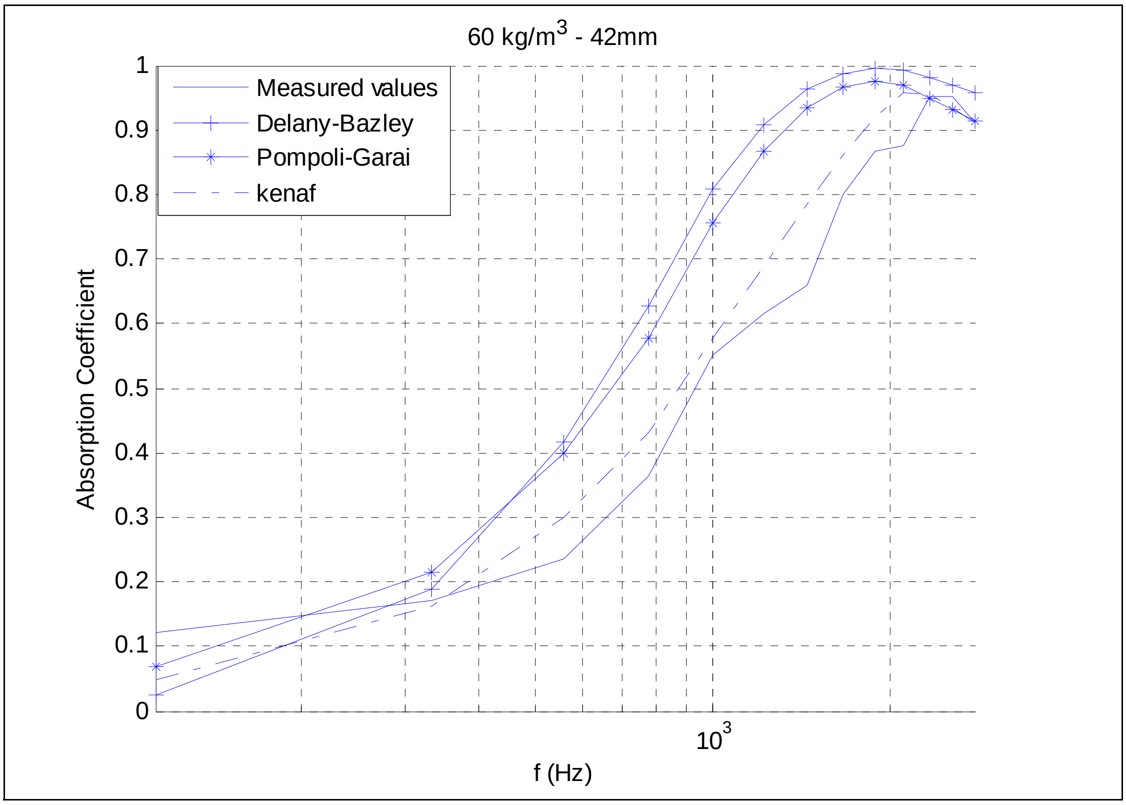

Figure 4 – Sound absorption values at normal incidence: comparison between measured values and calculated values.

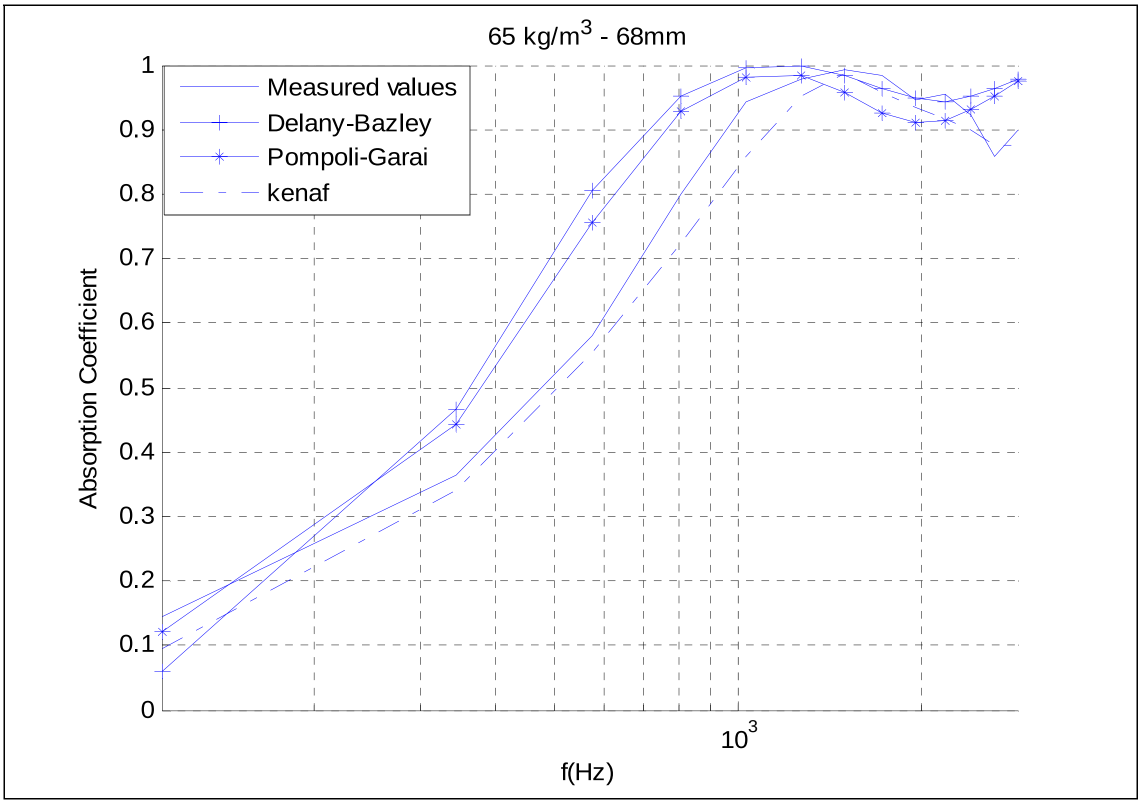

Figure 5- Sound absorption values at normal incidence: comparison between measured values and calculated values.

CONCLUSIONS

We have used the propagation constant and the specific acoustic impedance for the calculation of the sound absorption coefficient and the results are satisfactory. In this work, we have obtained coefficients better than the results of Delany & Bazley and others like Pompoli & Garai for polyester fibres. This can be observed in the table II, the mean deviation is smaller than that of the other methods. In future works concerning this bio-material, more samples will be analysed, with the objective of better adjusting the coefficients. Moreover, the validity of the method will be revised but not by adjusting the sound absorption coefficient but by adjusting the values of the acoustical impedance and the values of the propagation constant. The final objective is being able to use this bio-material in the acoustical world satisfactorily. We will study a micro-structural method in addition to this empirical method; therefore with both methods we hope to be able to describe the new material's acoustical behaviour.

AKNOWLEDGEMENT

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