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An investigation of flow resistivity for polyester fibres

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Introduction

Polyester fibres are an innovative class of products, that are quickly becoming widespread sound absorbers. They are often replacing glass wool and rock wool where health and safety issues are of importance. The main scope of this work is to investigate the effects of varying the bulk density of polyester fibres has on its flow resistivity. Few works can be found in the scientific literature devoted to the prediction of the airflow resistivity of fibrous materials [1-5]. The purpose of our work is to propose a new physical method to predict the flow resistivity of polyester fibre from the bulk density data.

Methodology

Given the nature of the material flow resistivity for ranging the bulk density is measured indirectly. Initially, the absorption coefficient is measured in an impedance tube [6]. The absorption coefficient data are then used to fit a Miki model [8] through the optimisation search:

$$\sum_n |\alpha_e(f_n) - \alpha_m(f_n, \sigma, l_s)| \rightarrow min$$

where α_e is the experimental absorption coefficient α_m is the predicted absorption coefficient f_n is frequency, σ is flow resistivity and l_s is the thickness of the sample. This procedure enables us to determine the flow resistivity which is taken as the only variable in the Miki model together with the layer thickness.

Experiment

Figure 1 illustrates schematically the impedance tube used to measure the absorption coefficient. The procedure involved the testing of 5 different fibres with diameters ranging from $17.5\ \mu m$ up to $39.2\ \mu m$ and densities ranging from $5\ kg/m^3$ up to $50\ kg/m^3$. For each fibre a fixed amount was taken and by decreasing the size of sample holder (l_s) of the impedance tube it was possible to achieve the desired bulk densities for the samples. Figure 2 presents a Miki model fitted to experimental data. The model predicts with high precision the absorption coefficient of the material (error<1%).

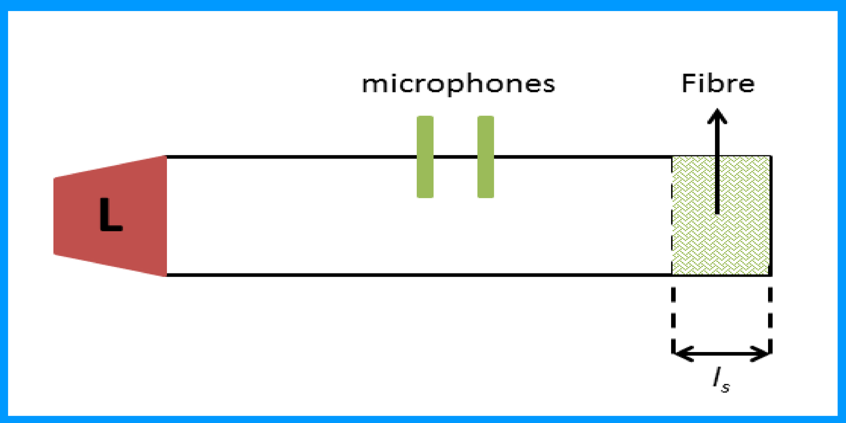

Figure 1: Impedance tube with fixed amount of fibre and varying the size of the sample holder (l_s).

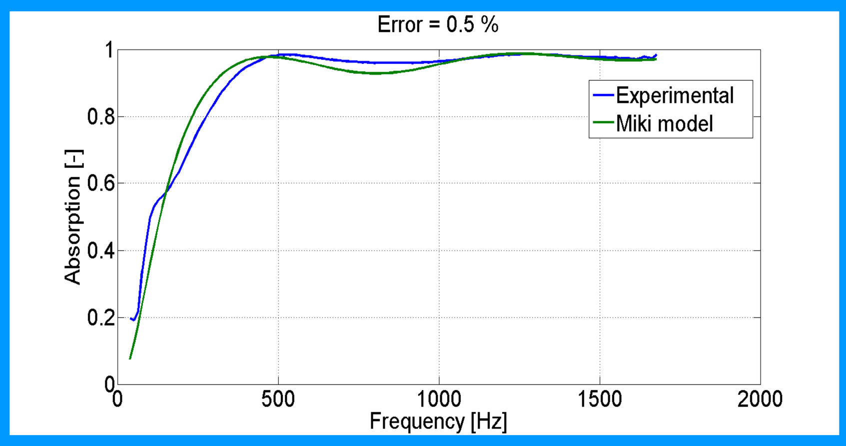

Figure 2: Experimental data (blue), Miki model (green). The fibre has $39.2\ \mu m$ and diameter and $15\ kg/m^3$ density.

Results

Figure 3 shows the flow resistivity for each sample as a function of density. This quantity was deduced from the impedance tube experiment.

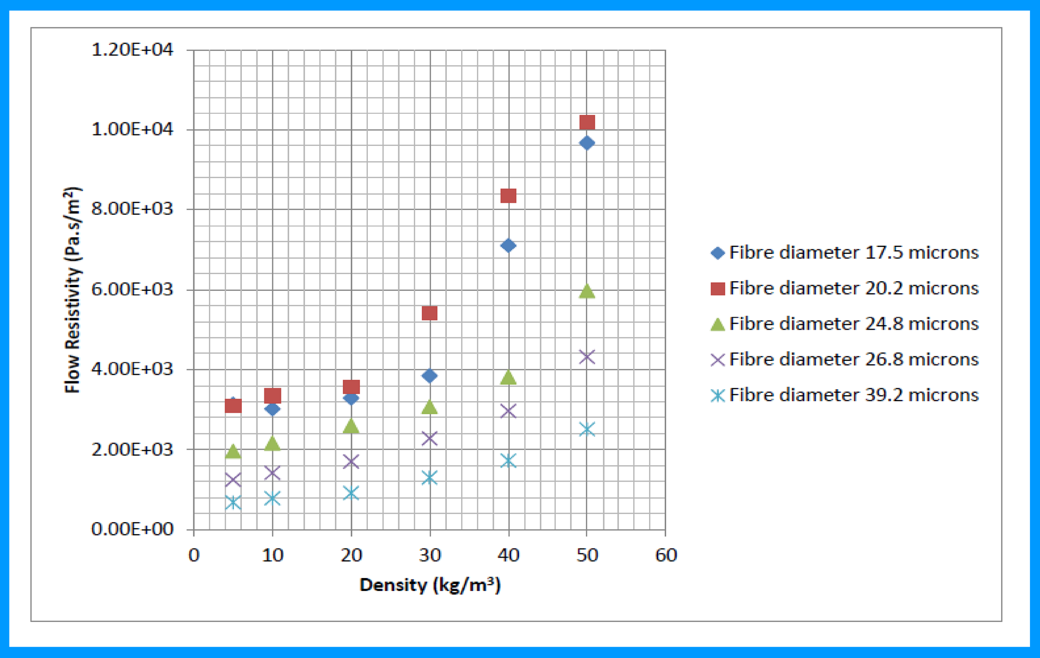

Figure 3: Flow resistivity for 5 polyester fibres with relation to density.

Garai and Pompoli suggested the following formula [5]:

$$\sigma = A\rho_m^B$$

where $A = 25.989$, $B = 1.404$ are free parameters and ρ_m is the bulk density of the fibre. This is a modification of Bies – Hansen empirical formula derived for fibrous materials [2]. In Figure 4, a comparison of the Garai – Pompoli predictions and experimental data is given. It is clear that the models predictions are not consistent with the data.

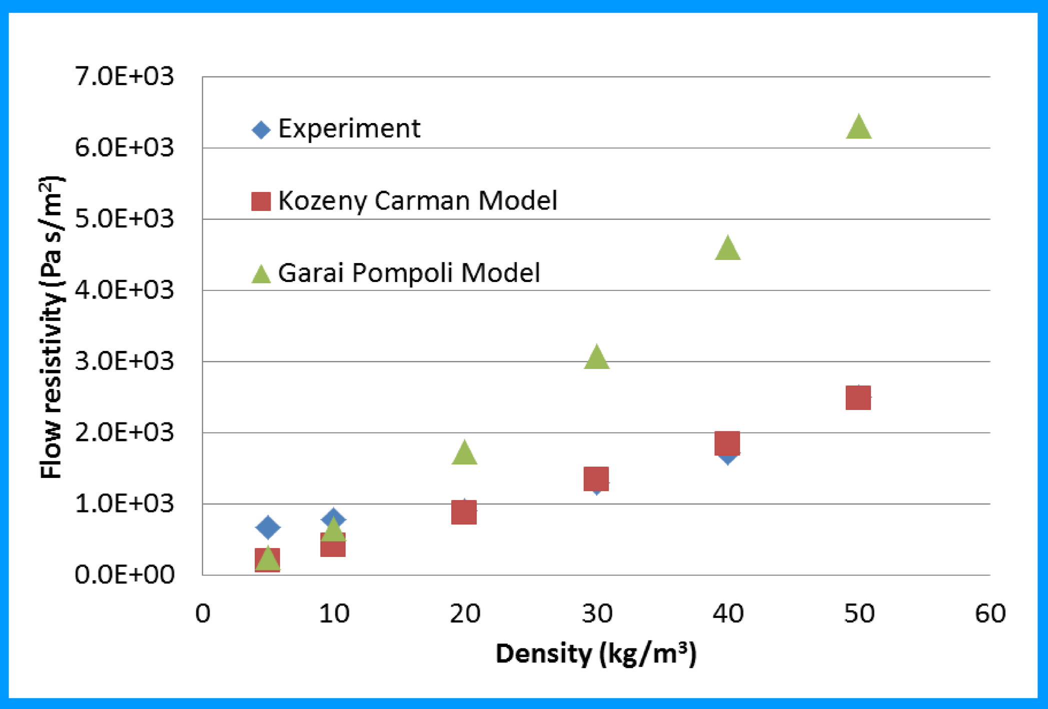

Figure 4: Flow resistivity for $39.2\ \mu m$ fibre with relation to density and the models used to predict the flow resistivity.

It is of interest to consider a more physical model to improve the fit between the model and data. For this purpose, the Kozeny - Carman equation was adopted [8-9]:

$$\sigma = \frac{72\mu l'(1-\varphi)^2}{l d_s^2 \varphi^3}$$

where φ is the porosity of the fibre, μ is the Viscosity of air, d_s is the diameter of the polyester fibre, l' is the mean value of the path through the medium and l is the depth of the sample. Furthermore, the porosity can be expressed as:

$$\varphi = 1 - \frac{\rho_m}{\rho_n}$$

where ρ_n is the density of a polyester fibre strand. Hence the Kozeny – Carman model can be plotted as a function of density and predict the flow resistivity. In Figure 4 it is clear that the proposed model performs better than the Garai – Pompoli model. If we define:

$$\gamma = \frac{(1-\varphi)^2}{\varphi^3}$$

Results (Continued)

From the Kopzeny – Carman model a linear dependency between the flow resistivity and γ is expected. Figure 5, confirms the predicted dependency, which provides an additional improvement to the Bies – Hansen model.

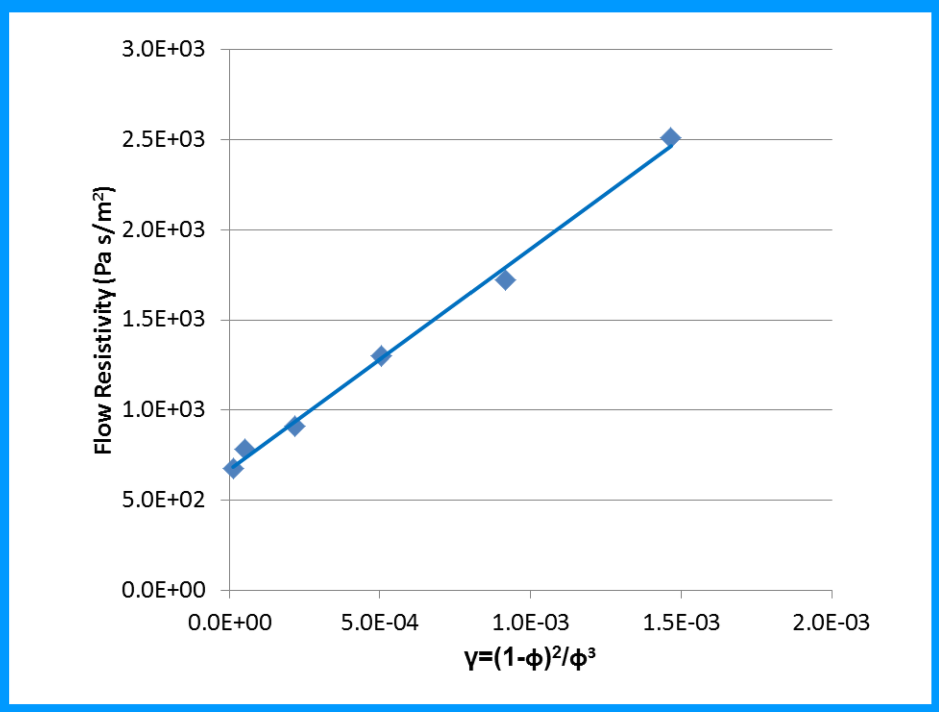

Figure 5: Flow resistivity for $39.2\ \mu m$ fibre with relation to γ.

Conclusion

The focus of this work was to improve the prediction of the flow resistivity of polyester fibre from the bulk modulus data. This information is important for the accurate modelling of the acoustical properties of absorbing products based on polyester fibre. In the past, a common approach adopted in the literature has been the empirical formula proposed by Bies – Hansen [2] or an alternative approach used by Garai and Pompoli [5]. The parameter inversion procedure and Kopzeny – Carman equation [8-9] were used. It was shown that the Kopzeny – Carman equation is a more accurate model for the prediction of the flow resistivity of polyester fibres and also allows us to explore the porosity dependency of flow resistivity. This model is physically sound.

References

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