



Air flow resistivity of high level compressed fibrous material

Lei Lei

► To cite this version:

Lei Lei. Air flow resistivity of high level compressed fibrous material. CFM 2015 - 22ème Congrès Français de Mécanique, Aug 2015, Lyon, France. <hal-03446441>

HAL Id: hal-03446441

<https://hal.science/hal-03446441v1>

Submitted on 24 Nov 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



HAL Authorization

Air Flow Resistivity of high Level compressed Fibrous Material

L. Lei, N. Dauchez, J.D. Chazot

Sorbonne universités, Université de technologie de Compiègne, CNRS UMR 7337, laboratoire Roberval, Centre de recherche Royallieu, CS 60319, 60203 Compiègne cedex, France.
email : lei.lei@utc.fr , email : nicolas.dauchez@utc.fr

Abstract :

To reduce the pass by noise of vehicles, multi-layer treatments made from fibrous materials are used around the engine. These materials are usually thermal compressed. Some research have been done to investigate the effect of compression, but few of them are concerned by high compression levels. In this paper we propose a physical based model to predict the variation of the airflow resistivity for fibrous materials submitted to a high level of compression. Validations have been done with experimental data for two types of fibrous materials. An accurate prediction of the resistivity variation for a high compressed fibrous material has been found with the proposed model.

Keywords : fibrous material, high compression rate, sound absorbing material

1 Introduction

To reduce the pass by noise of vehicules, sound barriers made of fibrous layers are placed in the engine compartment. In practice, they are manufactured by thermo-compression that significantly changes their properties. Several authors proposed formulas to derive the properties of the compressed material as function of uncompressed properties and compression rate n . Castagnède et al. [1-2] expressed the airflow resistivity as a linear function of the compression rate. Campolina et al. [3] pointed out that this formula is limited for low compression rates ($n < 1.5$). Garai and Pompoli [4] modified the equation of Bies and Hansen [5] and proposed a new empirical expression in order to fit polyester fibres with larger and more dispersed diameters and densities. They related the resistivity to the bulk density with two empirical constants. In the following, a physical model is presented to predict the airflow resistivity of fibrous materials under a predefined level of compression rates. It is based on the physical model of Tarnow [6].

2 Models

The same hypothesis used by Tarnow 1996 [6] are considered here. The fibrous materials are modelled as randomly distributed parallel cylinders. All the cylinders are taken with the same length and diameter,

and are considered as rigid. The porosity is also considered as higher than 0.9 and the distance between the center of any two cylinders is more than the cylinder diameter.

The air-flow resistivity of a flow along randomly placed cylinders is given by Tarnow[6] with :

$$\sigma = \frac{2(1 - \phi)\eta}{a^2[0.64 \ln(\frac{1}{1-\phi}) - \phi + 0.263]} . \quad (1)$$

It depends on the porosity ϕ , radius of a cylinder a , and the air viscosity η . This physical model is based on Voronoi polygons and Brinkman self-consistent procedure.

During a compression process, the only parameter that changes is the porosity ϕ related to the compression rate $n = h_0/h$ with

$$\phi_n = 1 - n(1 - \phi_1) , \quad (2)$$

where h_0 and h are the nominal and the compressed thickness respectively.

In the present work, the air flow resistivity is calculated from the previous equations as a function of the compression rate such as :

$$\sigma_n = n\sigma_1 \frac{\ln(\frac{1}{1-\phi_1}) + 1.5625(1 - \phi_1) - 1.1516}{\ln(\frac{1}{n(1-\phi_1)}) + 1.5625n(1 - \phi_1) - 1.1516} , \quad (3)$$

where ϕ_1 and σ_1 are the porosity and resistivity for the nominal thickness ($n = 1$), while ϕ_n and σ_n are the porosity and resistivity for the compressed thickness. From this equation, the resistivity can be predicted for any compression rate by giving the nominal flow resistivity and the nominal porosity of the material.

The present physical model is compared with there models of the literature. These models are now reminded. The model of Garai and Pompoli [4], give the air flow resistivity of fibrous materials as function of the density of the compressed material and two empirical parameters, $A = 25.989$ and $B = 1.404$:

$$\sigma = A\rho_m^B . \quad (4)$$

the empirical parameters. This model was derived from measurements on polyester fibre materials with a bulk density ρ_m between 12 and 60kg/m³, and a fibres diameter ranging from 18μm and 48μm. By expressing the mass as function of compression rate in equation (4), we obtain :

$$\sigma_n = n^B \sigma_1 . \quad (5)$$

Castagnède et al. [1-2] also developed the following heuristic formula for 1D and 2D compression case :

$$\sigma_n = n\sigma_1 . \quad (6)$$

$$\sigma_n = n^2\sigma_1 . \quad (7)$$

3 Results

Static airflow resistivity and porosity measurements have been done for glass wool and textile felt materials. A specific set-up was added to the resistivity measurement test bench to obtain a given compression rate. The experimental results are compared with the three models mentioned above.

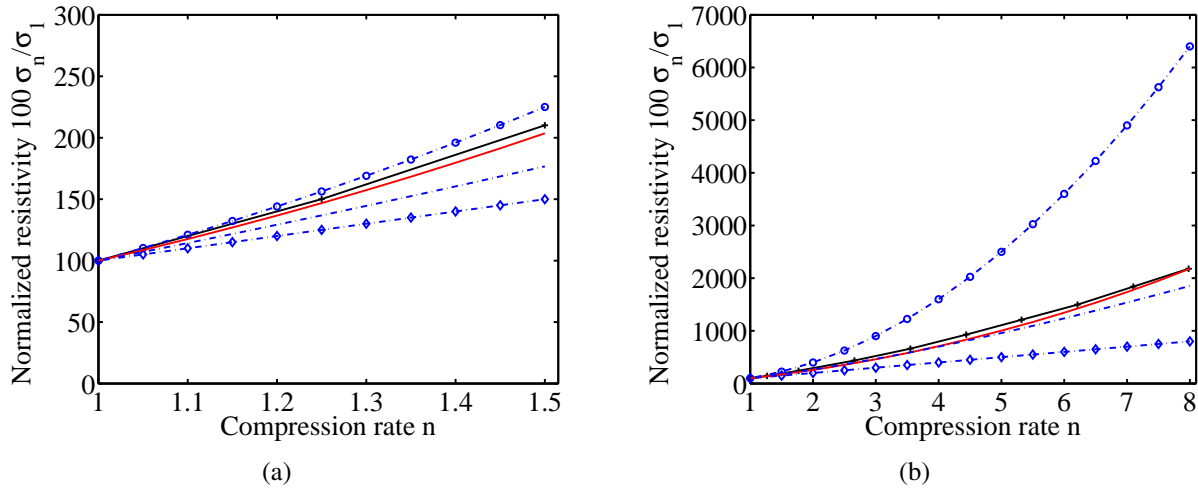


FIGURE 1 – Air flow resistivity as function of compression rate. Experimental data (—+) compared to different models : Castagnède 2002 linear (—○), Castagnède 2002 quadratic (—◇), Pompoli 2005 (—.), present model (—). (a) Textile felt with initial parameters : $h_1 = 16.2$ mm; $\phi_1 = 0.887$; $\sigma_1 = 36,299 \text{ Nm}^{-4}\text{s}$. (b) Glass wool with initial parameters : $h_1 = 20$ mm; $\phi_1 = 0.984$; $\sigma_1 = 50,891 \text{ Nm}^{-4}\text{s}$

Figure 1 shows the different models compared to experimental data of two types of fibrous materials (glass wool and textile felt). All the results are bounded by Castagnède et. al models. For a small compression ratio typically $n_{max} \leq 1.5$, all these models give an acceptable result. For a high compression rate typically $n_{min} > 4$, Castagnède models diverge. Garai-Pompoli and our model give a confident prediction, our model being slightly closer to experimental data.

Conclusion

In this paper, the air flow resistivity of fibrous materials is predicted for different compression rates with a physical based model. The input parameters are the nominal resistivity and the nominal porosity of the material. Comparisons with experimental data has been done on two types of fibrous materials. It has been shown that the present model is accurate to predict the resistivity of a highly compressed fibrous material. Further works are on going to test our model on other materials and to find out its sensibility to input parameters.

Acknowledgments

The authors would like to thank BPI for their financial support within the framework of the Ecobex AAP17 FUI project.

Références

- [1] Castagnède B, Aknine A, Brouard B, Tarnow V, Effects of compression on the sound absorption of fibrous materials, *Appl Acoust* 2000 61(2) 173–82.
- [2] Castagnède B, Tizianel J, Moussatov A, Aknine A, Brouard B. Parametric study of the influence of compression on the acoustical absorption coefficient of automotive felts. *Comptes Rendus de l'Académie des Sciences – Series IIB –Mechanics* 2001 ; 329(2) :125–30.
- [3] B. Campolina, N. Dauchez, N. Atalla, O. Doutres. Effect of porous material compression on the sound transmission of a covered single leaf panel. *Appl Acoust* 2012 ; 73 :791–797
- [4] Garai Massimo, Pompoli Francesco. A simple empirical model of polyester fiber materials for acoustical applications. *Appl Acoust* 2005 ; 66 :1383–98.
- [5] Bies DA, Hansen CH. Flow resistance information for acoustical design. *Appl Acoust* 1980 ; 13 :357–91.
- [6] V. Tarnow, "Air flow resistivity of fibrous acoustic materials" *J. Acoust. Soc. Am* 1996 ; 100 : 3706–3713.