View metadata, citation and similar papers at core.ac.uk brought to you by CORE

provided by Archivio della ricerca - Università degli studi di Napoli Federico II

Acoustic Performance Assessment of Innovative Blankets for Aeronautical Applications

Massimo Viscardi[a], Pasquale Napolitano[a], Daniela Siano[b] and Maurizio Arena[a]

[a]*Department of Industrial Engineering, Aerospace Section, University of Naples "Federico II"*
Via Claudio, 21 – 80125 – Naples, Italy

[b]*Vibro-acoustic Laboratory, Istituto Motori, CNR (National Research Council),*
Via Marconi, 4 – 80125 – Naples, Italy

Abstract. Polyurethane blankets are increasingly used for many aeronautical NVH applications. These foams, generally available in various thickness and density, are great sound absorber, therefore suitable in the aircraft interior. These foams are used as replacement to traditional combination of mineral wools / rock wool along with perforated panels, which require labor and also health hazardous. Polyurethane foams are generally available in various densities and thickness. The acoustic performance of sound absorbing poroelastic materials is characterized by intrinsic physical parameters like flow resistivity, and absorption coefficient. This paper presents a detailed discussion on measurement of flow resistivity as well as acoustic absorption coefficient of PU foam samples. Such numerical database of examined samples has been then validated through other laboratories activities, which shows the good accuracy of the methodology implemented within.

Keywords: Absorption coefficient, experimental validation, impedance tube, numerical simulation, PU foam.

PACS: 65.80.-g, 82.35.Np, 81.70.PgR

INTRODUCTION

The awareness on meeting the internal comfort targets is implying a substantial evolution of the assessments in aircraft design, aimed to deliver optimal vibro-acoustic, fire-resistant and recyclable properties[1-3]. In such research context, innovative materials, targeted at the NVH improvement of aircraft, enabling also light-weighting[4-6] without compromising the structural integrity, have been analysed. The most important parameter, which determines sound-absorptive and sound-transmitting properties of acoustic materials, is the flow resistivity: it depends on the porosity of a material as well as its tortuosity[1]. In the present paper, both numerical and experimental procedures have been addressed to evaluate these properties with respect to synthetic samples with different physical properties.

AFR MEASUREMENT METHOD

The most important parameter for absorption coefficient calculation is the AFR value of the material. The AFR is an intrinsic property for the material and generally does not change with thickness. The AFR can be measured with a standard approach according to ISO 9053 standard using a well-defined procedure and instrumentation[7-8].

The AFR measure is not done directly but is related to the pressure drop of moving flow through the material.

As shown in FIGURE 1 the flow moves through a pipe before across a calibrated sensor to characterize the pression drop due to a know AFR and after trough the sample where a second pressure drop is measured. The second pressure drop value is related to the specimen AFR and used for its measurement.

In TABLE (1), the list of samples analyzed and the result in terms of AFR is reported. The thickness, as said before, is not relevant for the AFR measure but is indicated, because used later for absorption coefficient calculation.

TABLE (1). Specimen list and AFR values measure experimentally.

Sample Name	Measure 1 [Nsm^{-4}]	Measure 2 [Nsm^{-4}]	Measure 3 [Nsm^{-4}]	Mean [Nsm^{-4}]
Polyester 1	15570.7	15865.3	16533.0	15989.7
Polyester 2	22104.8	21994.6	22339.2	22146.2
Thinsulate	185469.0	189713.0	168018.0	181066.7
Polyester 3	161521.0	152845.0	132536.0	148967.3

NUMERICAL MODEL

In order to calculate the acoustic absorption coefficient, a numerical model has been used. In this preliminary stage, only the AFR value of specimens is available. This parameter can be used as input for mono-parametric models like Delany-Bazley or Miki. In this case, the second model will be used as improvement of Delany-Bazley model[9].

The Delany-Bazley model, in some cases for multi layers, may lead to a negative impedance for very low frequencies denoting a non-physical behavior. The Miki model corrects this non-physical characteristic, introducing a correction for the low frequency range[10].

A second improvement provided to Delany-Bazley model by Miki is the extension of frequency range in which the model is valid. From his experiments, Miki noticed the model is also valid if:

$$\frac{f}{\sigma} < 0.01 \tag{1}$$

On the other side the upper limit of the model is still valid. Miki, in his formulation, also suggested to non-extrapolate the data outside the original boundaries provided by Delany-Bazley.

The model proposed by Miki shows an impedance defined in the form a+ib where a and b are real value and i denotes the complex unity:

$$Z_c = \rho_0 c_0 \left[1 + 5.50\left(10^3 \frac{f}{\sigma}\right)^{-0.632} - j8.43\left(10^3 \frac{f}{\sigma}\right)^{-0.632}\right] \tag{2}$$

$$k = \frac{\omega}{c_0}\left[1 + 7.81\left(10^3 \frac{f}{\sigma}\right)^{-0.618} - j11.41\left(10^3 \frac{f}{\sigma}\right)^{-0.618}\right] \tag{3}$$

The Miki model, as Delanz-Bazley one, returns the complex impedance (Z) and the wave number (k) for the specimen. From the Miki model the specific impedance and dynamic equivalent density (ρ) with the following expression:

$$K = \frac{Z_c \omega}{k} \tag{4}$$

$$\rho_c = \frac{k Z_c}{\omega} \tag{5}$$

The last step is to compute the superficial impedance that keeps in account for the thickness of the specimen as:

$$Z = -j\frac{Z_c}{\tan(Kh)} \tag{6}$$

where h is the thickness of the material. The absorption coefficient is finally calculated as:

$$\alpha = 1 - \left|\frac{Z - \rho_0 c_0}{Z + \rho_0 c_0}\right|^2 \tag{7}$$

Numerical Results

Using the previously model implemented in MatLab® environment, the absorption coefficients for tested samples have been calculated. In the following FIGURE 1, the behavior of absorption coefficient respect to the thickness and respect to the AFR value, are shown.

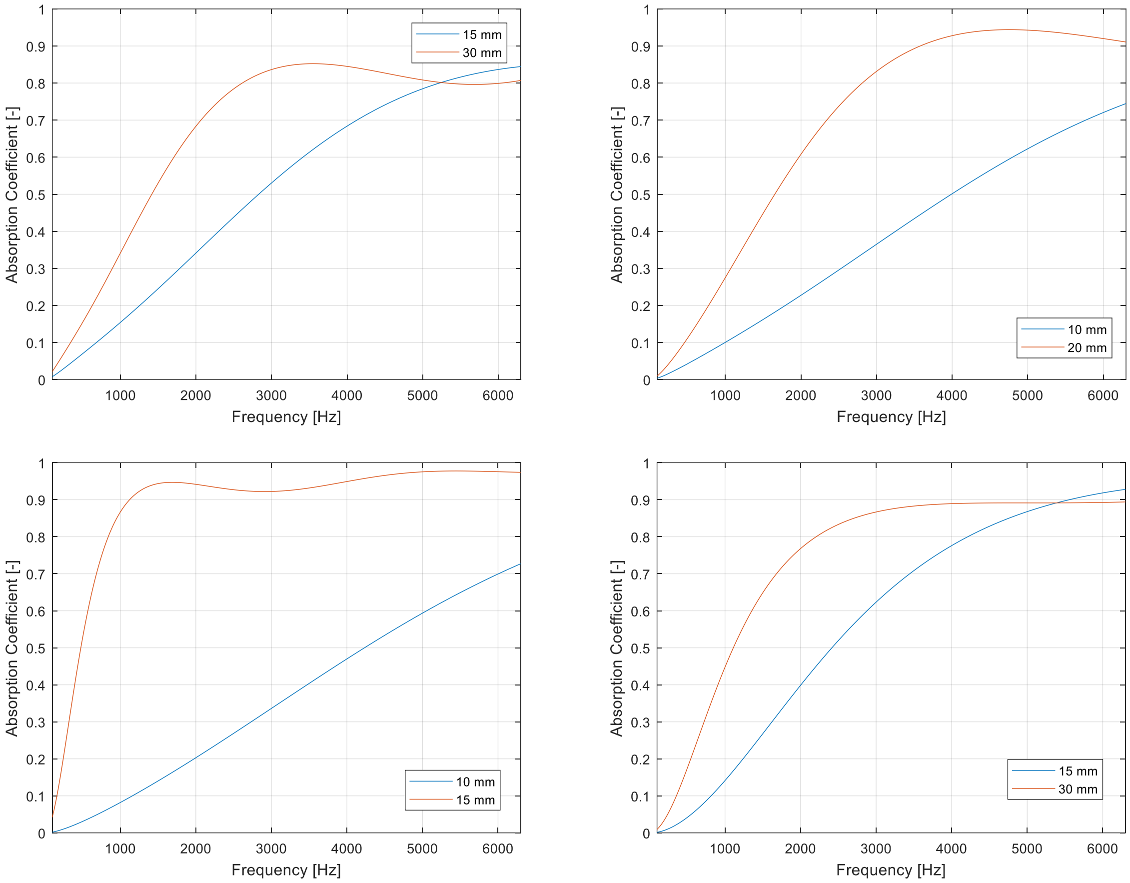

FIGURE 1. Numerical results using Miki model and air flow resistivity from TABLE 1. Upper left polyester 1; Upper right polyester 2; bottom left thinsulate; bottom right polyester 3.

EXPERIMENTAL VALIDATION

The last step is the experimental validation of the model developed in the previously section. The experimental validation will be done using the impedance tube, also known as Kundt tube.

Results Comparison

In this section, the experimental results have been compared to numerical ones to validate the preliminary model[11-12]. For the experimental validation, a wide range of AFR and thickness has been chosen to check the model accuracy over a wide range of specimens. In the FIGURE 2, the results of numerical model and experimental tests have been compared.

From FIGURE 2 is shown as the numerical model prediction is really close to experimental data. The AFR measured is a good input for the model. As supposed, Miki model shows a good predictivity level being a good tool for absorption coefficient estimation.

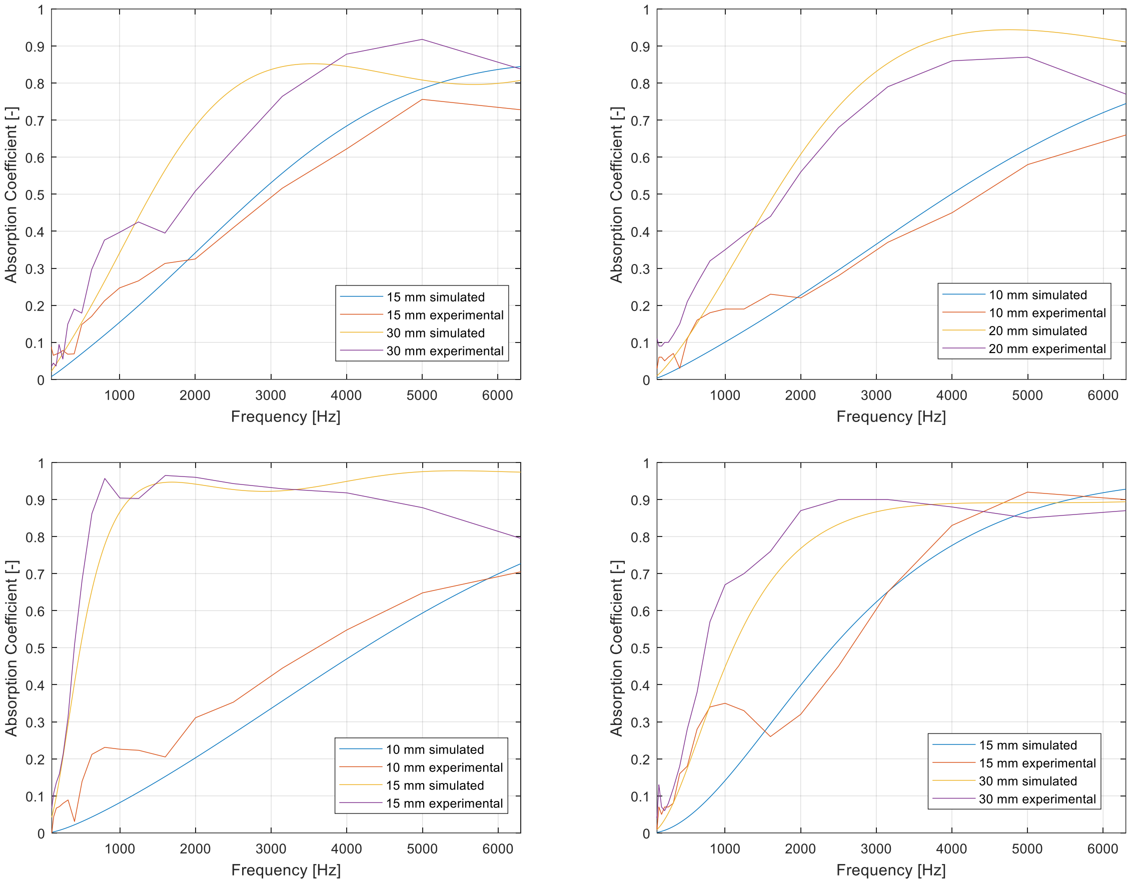

FIGURE 2. Experimental to numerical comparison. Upper left polyester 1; Upper right polyester 2; bottom left thinsulate; bottom right polyester.

REFERENCES

1. M.P. Joshi, P. Shravage, S.K. Jain and N.V. Karanth, "A Comparative Study on Flow Resistivity for Different Polyurethane Foam Samples" in *Journal of Acoustical Society of India* 38, pp. 153-157 (2011).
2. M. Viscardi, M. Arena and D. Siano, "Experimental and numerical assessment of innovative damping foams" in *International Journal of Mechanics* 10, pp. 329-335 (2016).
3. M. Viscardi, M. Arena and D. Siano, " Design and testing of a prototype foam for lightweight technological applications" in *International Journal of Mechanics* 10, pp. 383-395 (2016).
4. M. Viscardi, M. Arena and D. Siano, "Vibro-acoustic response of a turboprop cabin with innovative sidewall viscoelastic treatment" in *24th International Congress on Sound and Vibration, ICSV* (2017).
5. D. Siano, M. Viscardi and M.A. Panza, "Automotive Materials: An Experimental Investigation of an Engine Bay Acoustic Performances" in *Energy Procedia* 101, pp. 598-605 (2016).
6. M. Viscardi, M. Arena, D. Siano and M. Brandizzi, "Validation Of An Innovative Viscoelastic Treatment, Integrated On A Real Vehicle Mock-Up for the Internal Vibro-Acoustic Improvement" submitted for the *International Journal of Vehicle Noise and Vibration IJVNV* (2017).
7. ASTM C-522: ASTM International standard, Standard Test Method for Airflow Resistance of Acoustic Materials.
8. ISO 9053; Determination of Airflow Resistance of Acoustical Materials.
9. M. E. Delany and E. N. Bazley, "Acoustical properties of fibrous absorbent materials" in Applied Acoustics 3, pp. 105–116 (1970).
10. Y. Miki, "Acoustical properties of porous materials-Modifications of Delany-Bazley models" in *Journal of the Acoustical Society of Japan (E)* 11, pp. 19-24 (1990).
11. M. J. Crocker, Handbook of Acoustics, New York: John Wiley & Sons, 1998.
12. H. Meng, Q.B. Ao, H.P. Tang, F.X. Xin and T.J. Lu, " Dynamic flow resistivity based model for sound absorption of multi-layer sintered fibrous metals" in *Science China Technological Sciences* 57, pp 2096–2105 (2014).