Influence of a fibrous material compression on the sound transmission loss of a covered panel

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Introduction

The general context of this study is the reduction of cockpit internal noise. During installation, glass wool blankets used as thermo-phonic insulation are compressed to a certain degree between equipments, cables, ventilation grids and fuselage panels. The aim of this paper is to determine the influence of compressing a poro-elastic material lined with an aluminium plate on the sound transmission loss (TL). For this purpose the difference of the compressed and uncompressed TL (hereafter called Delta TL) are compared both analytically and experimentally.

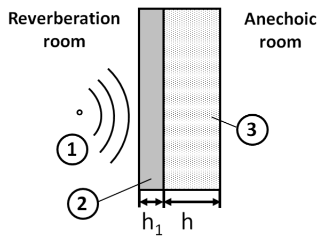

Figure 1: Studied structure: 1-diffuse acoustic field excitation, 2-aluminium plate, 3-fibrous material.

The tested structure is represented in Fig. 1. It is composed of an aluminium plate, having a thickness of $h_1 = 5$ mm, and a porous layer, with nominal thickness $h = 50.8$ mm. 2 fibrous materials, having densities of 9.6 kg.m^{-3} and 8 kg.m^{-3} are tested under 3 configurations: uncompressed, 20% and 50% compressed. The compression is achieved uniformly along the thickness direction using a metallic grid. The structure has a surface area of 0.73 m^2 and is placed between a reverberant and an anechoic room. It is excited by a diffuse acoustic field (DAF) in the 300 Hz - 5 kHz frequency range.

At first, the variation in frame properties with compression are determined in order to feed the analytical model to compute the TL [1]. Castagnède et al. [2, 3] and Wang et al. [4] proposed simple formulae for the porous layer properties (porosity, flow resistivity, tortuosity, viscous and thermal characteristic lengths) to account for one-dimensional compression under normal incidence. Here, the equations are supposed valid for a DAF excitation and are employed to compute the properties for a given compression.

1. Compression effect on airflow resistivity

The airflow resistivity of the compressed fibrous layer is [2, 3]: $\sigma^{(n)} = n\sigma^{(1)}$, where $\sigma^{(1)}$ is the nominal resistivity and n is the compression rate. It is defined as: $n = \frac{h_0}{h}$, where h_0 and h are the nominal and the compressed thickness, respectively. A 20% and 50% thickness compression corresponds to $n = 1.25$ and $n = 2$.

The airflow resistivity measurement procedure is described in [5]. Errors are mainly associated with pressure fluctuations caused by airflow leaks around the sample and tend to increase with compression. Tested samples have a 99.9 mm diameter and a 50.8 mm thickness. The compression is achieved using an adapted grid not disturbing the airflow. Tests on three different samples show that results are repeatable for all compression rates. Fig. 2 shows that at high compression rates the model is not accurate. The model deviate from measured values

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starting at n=1.5. For this reason, measured values will be used in TL computations.

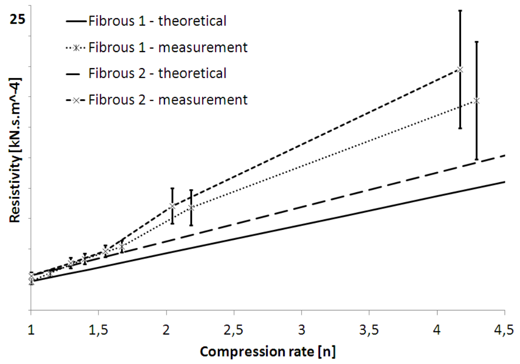

Figure 2: Airflow resistivity as a function of compression for fibrous 1 (9.6 kg.m^{-3}) and fibrous 2 (8 kg.m^{-3}).

2. Compression effect on the sound transmission loss

The transmission loss of the plate-porous structure is computed using the transfer matrix method with a limp assumption for the fibrous layer [1]. Tested fibrous samples are uniformly compressed along 100% of their surface using a rigid grid with 43 mm x 33 mm cell size. Delta TL results are shown in one-third octave bands in Fig. 3 for the two fibrous materials. Theory and experiments agree well in the mid-frequency range, where a decrease in the TL is observed of about 1 dB for a $n = 1.25$ compression and 4 dB for a $n = 2$ compression. This effect is found to be caused by an increase with compression of the quarter-wavelength resonance in the thickness of the fibrous. The radiation efficiency of the system, computed under 2 different excitation fields (DAF and structure-borne [6]), increases with compression in the same frequency range, showing that this effect is indeed caused by the porous layer. Additionally, another reduction in the TL is observed in experimental results at the critical frequency of the plate (2300 Hz).

The fibrous airflow resistivity is an important parameter to compute the quarter-wavelength resonance and it has been shown experimentally that predictions underestimate measured values. For a typical aircraft sidewall the reduction in the TL has been found much lower since compression happens locally and not at 100% of the surface as in the studied case. Moreover, the method derived by Doutres & Atalla [7] to separate absorption and transmission contributions of each layer to the total sound transmission loss of a double-wall structure could be employed to study this effect for a more representative configuration including the internal panel.

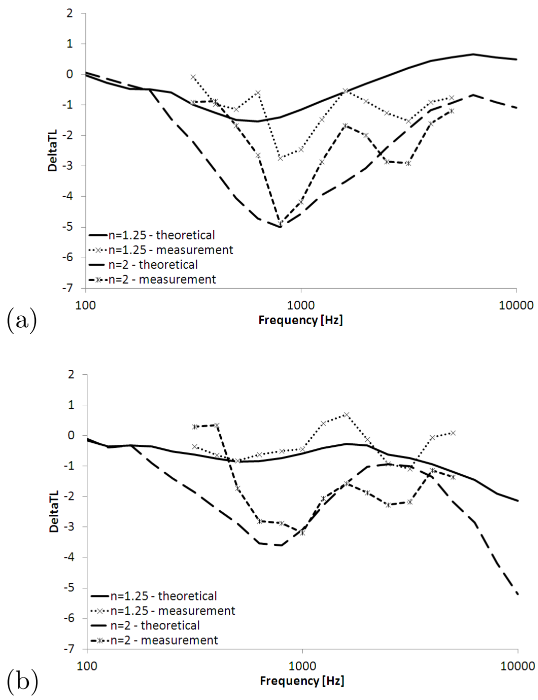

Figure 3: Influence of porous layer compression on the TL: a) fibrous 1 (9.6 kg.m^{-3}), b) fibrous 2 (8 kg.m^{-3}).

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