Enhancement of the low frequency performance of thin, film-faced layers of foam by surface segmentation

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Background

While the control of high frequency noise by the use of porous treatments is relatively straightforward, it is correspondingly difficult to control low frequency noise owing to the general requirement that a porous layer should be a significant fraction of a wavelength in depth. Thus, it is of interest to develop low frequency sound absorbing treatments that are relatively compact by the use of surface treatments. Here, we illustrate an approach, in which a surface film is cut, to allow the incident sound to communicate directly with the air within the foam behind the film facing.

The present work was inspired by standing wave tube measurements of film-faced foams. It was found that measurements of unfaced foam layers, or of foam layers with a loosely attached film layer could be reproduced well by existing theories. However, when a film was bonded to the surface of the foam layer, the results did not conform to the expected values, and showed an anomalous absorption peak at relatively low frequencies [1]. Upon careful examination of the experimental arrangement, it was noticed that there was a narrow gap around the circumference of the film facing: i.e., there was a leak around the edge of the sample. When that leak was sealed by using a bead of silicone sealant, the anomalous low frequency peak disappeared, and the absorption was then as expected for a continuous film-faced layer. Thus, it was apparent that the low frequency absorption peak was due to the presence of the thin gap around the circumference of the foam layer.

These observations led to the conjecture that the circumferential slit around the edge of the film created a thin "neck" that connected with the air in the foam-filled space behind the film to create a Helmholtz-like resonator, which was "tuned" to a relatively low frequencies owing to the narrow slit which created a large inertial element which reacted against the stiffness of the air trapped within the foam layer. It was subsequently found that when an appropriate, Helmholtz resonator-like impedance was added in parallel to the impedance of the continuously film-faced foam, the measured results were approximately reproduced, including the low frequency absorption peak. The latter finding suggests that it is possible to create effective, and thin, low frequency absorbers by systematically scoring the surface of a film-faced foam to create narrow gaps. However, the first task is to establish whether the measured results can be reproduced using numerical models.

Discussion

The experimental configuration shown in Fig. 1 was modelled by using the finite element method. This numerical model is based on the (u,p) weak formulation of the Biot equations proposed in [2]. The membrane is assumed to be a limp and thin impervious layer. It is modelled as a coupling condition between the air and the poroelastic material [2]. Two configurations have been tested: i) a circular impedance tube (shown below); and, ii) an infinite array of elementary cell. All the details of the numerical models can be found in Refs. [3,4]. A comparison between the impedance tube experiments and numerical simulations is presented in Fig. 2.

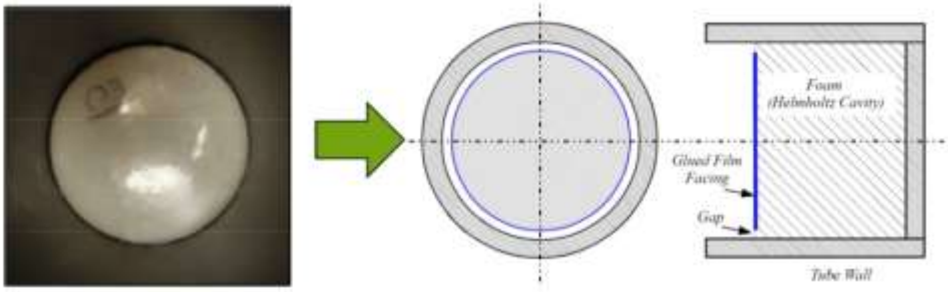

Figure 1: Test sample, 25 mm in depth, in the impedance tube.

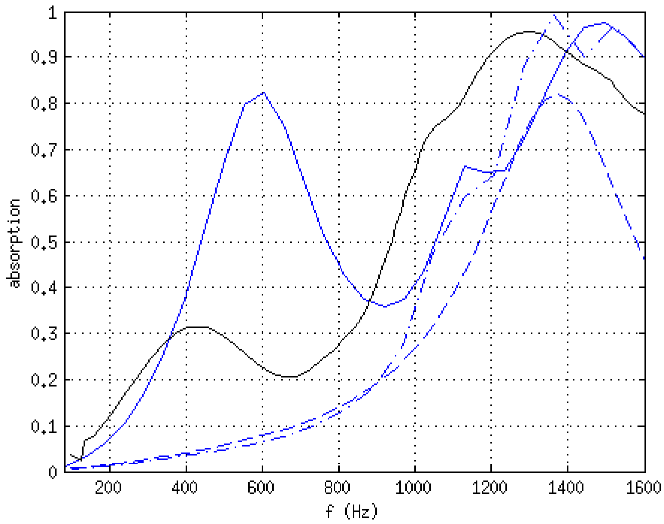

Figure 2: Comparison between experiment (solid black line) and simulation (blue lines): Solid line, clamped foam and partial membrane with 1 mm gap; dashed line, sliding foam and full membrane; dash-dotted line, clamped foam and full membrane.

The behavior of a foam layer with clamped or sliding condition in the tube, and totally covered by the membrane is shown in Fig. 2: both conditions lead to an absorption very different from the experimental data. On the other hand, the computation performed with a 1 mm gap (and clamped edges) captures most phenomena : i.e., the first and the second main peaks and the small one close to 1050 Hz (but both the frequencies and the amplitudes are overestimated). Work is ongoing to identify the origins of these discrepancies, especially the experimental uncertainty on the boundary conditions and on the skeleton properties. Work is still needed to indentify the controlling parameters that would allow a simple estimation of the resonance frequency.

References

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