Amplitude dependence of melamine foam absorption coefficient: nonlinear effects and Biot resonance

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We report experimental results and their interpretations on nonlinear acoustic effects observed in a Kundt tube characterization experiment for some particular foams. The presented results are obtained with a melamine foam of thickness 51 mm. When a measurement is performed in a standard Kundt tube for different acoustic levels, the computed absorption coefficient of the sample is observed to be different. In Fig. 1, such absorption coefficient measured in a standard Kundt tube is shown in grey lines, for different noise excitation levels (100, 105, 110, 120, 130, 135, 140 dB respectively). For comparison, the same sample has been characterized using an acoustic impedance sensor[1], adapted to perform impedance measurement of porous media, at much lower acoustic excitation level [1, 2]. The corresponding result is presented in Fig. 1 in blue line. A modeling of the absorption coefficient via the Biot theory is plotted in red circles on the same figure. By analyzing the model results, the observed drop in absorption coefficient can be attributed to the first longitudinal Biot resonance of the sample. This drop is clearly observed experimentally with the impedance sensor. There is a fair agreement between the impedance sensor result and the model. However, the Kundt tube results exhibit a strong disagreement with the model, more and more pronounced when the excitation level is increased. This discrepancy can be attributed to the quite large achieved excitation levels and could possibly disappear at lower levels than those presented here.

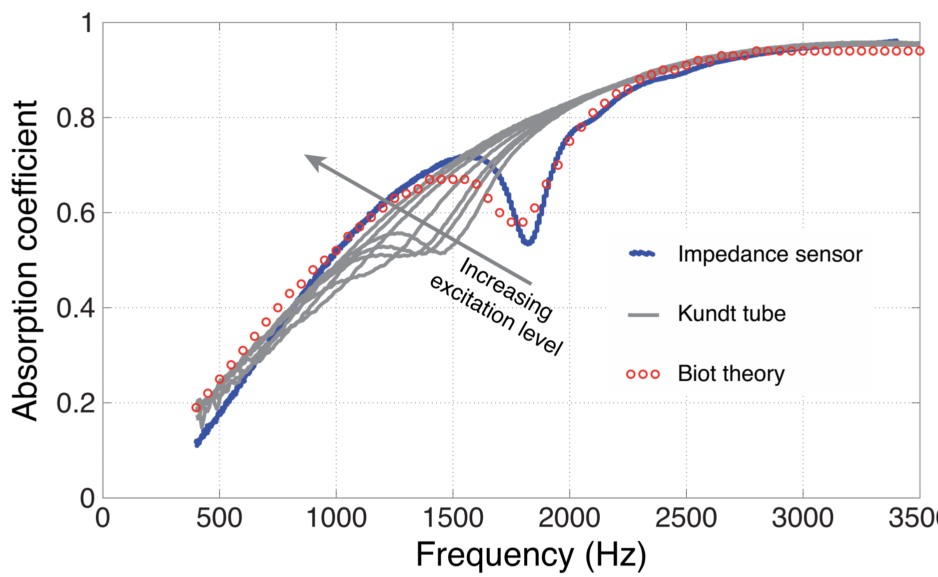

Figure 1: Absorption coefficient of a melamine foam measured with a standard Kundt tube at different excitation amplitudes (in grey lines). Absorption coefficient measured via an acoustic impedance sensor (refs) in blue line. The model based on Biot theory is shown for comparison in red circles.

The drop which exists but is not located correctly in frequency at the smallest excitation level tends to shift to lower frequencies and disappear with increasing excitation level. For the highest excitation level

[1]This sensor is distributed by Centre de Transfert de Technologie du Mans (CTTM)

(140 dB), the absorption coefficient almost follows what would be expected in the case of the equivalent fluid approximation. In order to extract the drop in absorption coefficient, and its behavior as a function of wave amplitude, curves are substracted to the one for 140 dB and presented in Fig. 2.

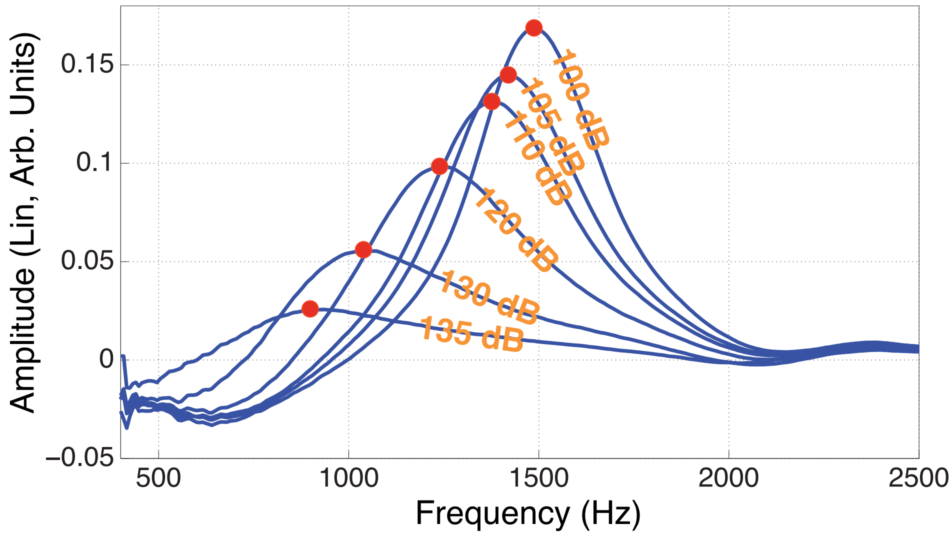

Figure 2: Deviation of the measured absorption coefficient from the one measured at 140 dB in the case of the Kundt tube characterization.

The obtained curves are comparable to resonances, as expected from the interpretation of the drop in terms of Biot resonance. These resonances exhibit downward frequency shift and decreasing quality factors as a function of increasing excitation level. These effects of nonlinear resonances are well-known in the so-called mesoscopic solid materials or micro-inhomogeneous materials (a wide class of granular or damaged solids, most of the time containing soft inclusions inside a rigid matrix) [3]. By analyzing the amplitude dependence of this nonlinear resonance effect, we are able to isolate the nonlinearities involved in the behavior of the solid skeleton of the foam. Consequently, these results open the way to a deeper characterization of the foam via its nonlinear solid skeleton elasticity and the measure of a nonlinear parameters. It also shows that standard characterization experiments of porous media could provide importantly altered results, due to the nonlinear effects reported here.

Further experimental and theoretical developments based on the quadratic hysteretic behavior of the solid skeleton elasticity in the frame of Biot theory (in the continuation of [4]) are currently under consideration and will be presented.

References

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