Acoustical investigation of aerogel granules modeled as a layer of poro-elastic material

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1 Introduction

Aerogels are defined as mesoporous materials obtained by replacing the liquid phase within a gel by a gaseous phase, typically air. This underlying mesoporous structure provides aerogels unique macrostructural properties such as ultralow density, high transparency, and low thermal conductivity [1]. Given their ultralow density, aerogels are also an attractive, lightweight solution for noise control applications. Recent studies have shown that the acoustical properties of granular aerogels are very different from those observed for other granular media [2]. In this presentation, we present results from our recent investigation of the acoustical behavior of Enova IC3100 aerogel granules. Manufactured and commercially sold by Cabot Corporation, IC3100 aerogels are characterized by their comparatively smaller granule dimensions. Our previous experimental measurements [3] show that the acoustical performance of the IC 3100 aerogel granules differs from conventionally used sound absorption materials; multiple, lightly damped depth resonances with large peak values of absorption coefficients are observed low frequencies. Here, we present results from our attempt to model the acoustical behavior of IC3100 aerogels. The acoustical-related bulk properties required for the Johnson-Champoux-Allard (JCA) model are calculated using an inverse characterization approach. These properties are then used to model the acoustical behavior of the granular aerogel layer using the Biot theory for porous media.

2 Methods

The aerogel's bulk properties were first input into the Johnson-Champoux-Allard (JCA) model [4,5] for the prediction of the material's bulk modulus and effective density. The Biot theory [6] was then applied to predict the fundamental acoustical properties such as the material's wavenumber(s) based on the bulk modulus and effective density predicted by using the JCA model. The characterization of the bulk properties was achieved by fitting the experimentally measured normal incidence absorption coefficients of a layer of aerogel resting on a hard-backing using a JCA-Biot-Transfer Matrix Method/Arbitrary Coefficient Method formulation [7,8], and by identifying the bulk properties which would provide the closest modeled results to the measured data. We examine the choice of modelling the aerogels as either a limp porous medium or as a poro-elastic medium.

3 Results

To avoid additional complexity, the IC 3100 aerogel was originally assumed to be limp porous medium, and the characterized bulk properties obtained by using Biot limp porous model (limp model) are shown in the second row of Table 1. On the other hand, the absorption coefficients of 1-inch and 2-inch layers of IC 3100 aerogel granules modeled given the limp model-characterized bulk properties are shown as the green-dot-dashed lines in Figure 1 (a) and (b), respectively. By comparing the green lines with the measured results (red solid lines), an obvious under-estimation of absorption coefficients can be observed in the low frequency area, which indicates an under-estimation of damping at this region. Therefore, to take one step forward, the aerogel was then modeled as a poro-elastic medium by using the Biot poro-elastic model (elastic model) to take the material's bulk elasticity properties including the loss factor, η_m, into account. There were 7041 line-spaced frequencies ranging from 600 to 6100 Hz involved into the modeling process to match the measurement frequency steps setting. Correspondingly, by introducing a 7041-step loss factor that dynamically decreases as the frequency increases, and by making it logarithmically spaced in ranges as listed at the end of the second and third rows in Table 1 for the 1-inch and 2-inch cases, respectively, it can be observed by comparing the blue-dashed lines in Figure 1 with the measured data that the dynamic loss factor realizes better absorption fittings for both cases.

Table1: Bulk properties characterized by fitting the measurements.

IC 3100 aerogel granules	σ [Rayls/m MKS]	ϕ	α_∞	Λ [μm]	Λ' [μm]	ρ_b [kg/m^3]	E_1 [Pa]	ν	η_m
Limp model 1-inch / 2-inch	10,457,000	0.999	3	36.08	36.08	39.86	N/A	N/A	N/A
Elastic model 1-inch	10,457000	0.999	3	36.08	36.08	39.86	775	0.396	20 to 0.0063
Elastic model 2-inch	10457000	0.999	3	36.08	36.08	39.86	775	0.396	10 to 0.0001

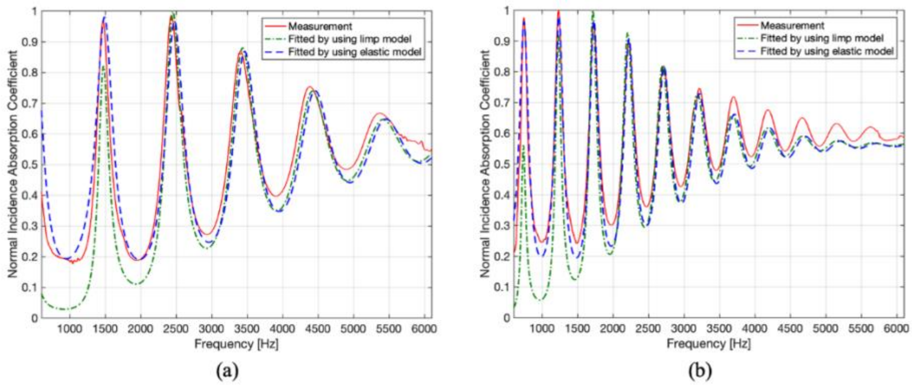

Figure 1: Absorption coefficients of (a) 1-inch, (b) 2-inch layer of IC 3100 aerogel granules.

4 Conclusions

The acoustical behavior of Enova IC3100 aerogels is modeled using the Biot theory for porous materials. Our results show that IC3100 granules show unique low-frequency acoustical properties that cannot be adequately captured using Biot's limp porous media formulation. Instead, we show that the poro-elastic model with a logarithmically decreasing loss factor provides a better match with experimental data.

References

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