SAPEM2017/58
On the conditions for perfect absorption of sound by rigidly-backed layers of porous materials

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In this work we present and discuss the conditions to observe perfect sound absorption by rigidly-backed layers of rigid-frame porous materials. We theoretically analyze different configurations of increasing complexity to obtain the conditions to observe perfect absorption. First, a single layer of porous material, second, a layer of porous material with an air gap (air plenum), and, third, and an optimized multilayer structure. We show that to obtain perfect sound absorption at normal incidence and at the first quarter- wavelength resonance of a single rigidly-backed porous layer, the thickness of the material is strongly related to its flow resistivity. In particular, perfect sound absorption is observed when the quarter-wavelength resonance is around the characteristic Biot's frequency of the porous media, and the optimal thickness of the layer is 4.3 smaller than the perfectly absorbed wavelength. We analyze the behaviour of the structure when the angle of incidence is tilted, showing that perfect sound absorption is also produced for other incident angles and frequencies. Then, an air gap is introduced between the porous layer and the rigid backing. The gap allows to produce perfect sound absorption for structures thicker than the optimal one and for media with large intrinsic attenuation, i.e., for materials with high flow resistivity. Finally, an optimized multilayer structure is proposed, which presents broadband and perfect sound absorption. The existence of the perfect absorption is related to the impedance matching, which is produced when the intrinsic losses of the system exactly compensate the leakage of the structure due to resonance. Thus, the total thickness of any multilayer porous material structure is constrained to its quarter-wavelength resonance and material properties, because of the lack of deep-subwavelength resonance in the system.