Camille Perrot

(Université Gustave Eiffel, France)

What are the microstructural features having a significant effect at the upper scale in acoustic materials? Understanding the physics and guiding the manufacturing process

Abstract (not so short)

What is the microscopic basis of macroscopic transport in poro-elastic materials? How do macroscopic transport properties depend on pore-structure? These are two of the many questions that have dominated studies of sound waves through microscopically-disordered materials. In light of the manifest technological importance of determining the effective parameters of disordered heterogeneous materials (e.g. composite and porous media), an enormous body of literature has evolved based upon direct measurement, empirical relations, and approximate as well as rigorous theoretical methods [see Gibson and Ashby (1988); Adler (1992); Torquato (2001); Auriault et al. (2009) and references therein]. Performing direct measurements on each material sample, for possible multi-phase property values and all volume fractions, is prohibitive from a time and cost standpoint. Empirical relations are more useful for correlating data rather than predicting them. Since bulk properties are sensitive to the details of the microstructure, a broader approach is to calculate the properties from the microscopic structure (microstructure) of the disordered material; one can then relate changes in the microstructure quantitatively to changes in the macroscopic parameters. For general random media, the complexity of the microstructure prevents one from obtaining the effective properties of the system exactly. Some progress can be made with idealized structures. Idealized structures are useful since they: (i) enable one to test the merits of simple geometries and computer experiments; (ii) as successfully more geometrical information is incorporated, the effective property estimates become progressively more comparable with experiments; (iii) one of the microstructural model can typically provide a good estimate of the properties for a wide range of manufacturing conditions. In acoustics, the transport phenomena that are of interest are essentially heat conduction, inertial flow and viscous flow; together with elastic properties of a porous medium. Hence, the situation can be summarized as follows: field equations corresponding to four basic phenomena must be solved for three basic model geometries (cellular, granular, fibrous). The microscopic level corresponds to the knowledge of the value of the fields at every point. The macroscopic level is obtained by averaging the relevant microscopic fields over the virtual sample. It is this macroscopic level that is of interest for the engineers who wish to know the overall transport coefficients that relate the flux to the driving forces; and the effective elastic properties that enable the determination of the deformation under stress of the porous materials. One of the purpose of this communication is to provide a brief review of that popular micro-macro approach, that relate pore structure to transport coefficients (rigid assumption), so that their significance are clearly understood. Recent progress that we have made on the problem of determining the long wavelength effective acoustical properties of random heterogeneous media from knowledge of the morphology is reviewed and extended. This communication will primarily deal with non-woven and heterogeneous cellular structures.