Journal of Sound and Vibration 329 (2010) 4333–4334

Contents lists available at ScienceDirect

Journal of Sound and Vibration

journal homepage: www.elsevier.com/locate/jsvi

Book Review

Propagation of Sound in Porous Media: Modelling of Sound Absorbing Materials, 2nd edition, J.F. Allard, N. Atalla, John Wiley & Sons, Ltd. (2009), ISBN: 978-0-470-74661-5

The first edition of this book became a rarity long time ago, so the second edition has been long awaited. The book is considerably extended and new material has been added to reflect current achievements in acoustics of porous media.

Chapter 1 describes the propagation of plane waves in isotropic fluids and solids. The basics of vector notations are explained at the beginning. The wave equations are derived separately for inviscid fluids and elastic isotropic solids. Examples given in this chapter help to visualise the difference between shear, longitudinal strain, unidirectional stress and compression by a hydrostatic pressure. This chapter also provides a useful introduction for those not familiar with the basics of elasticity. I believe it could be useful to give some attention to wave propagation in viscous fluids in this chapter. The analogy between porous layer and viscous fluid is exploited in the later chapters and this analogy would be easier to comprehend, if the wave equation for isotropic viscous fluid were derived in Chapter 1.

Chapter 2 considers acoustic impedance at normal incidence, assuming that the porous layer is replaced by an equivalent viscous fluid. The impedance translation theorem and the corresponding relation for the pressure reflection coefficient are introduced. Definitions of porosity and flow resistivity are given prior to the introduction of Delany's and Bazley's empirical laws. This chapter does not look like a logical continuation of the previous one. It could be difficult for novices to grasp the idea that both characteristic impedance and wavenumber can be complex quantities. It would be helpful to emphasize that this fact is the consequence of viscous and thermal interactions between the fluid and the rigid frame. Also it seems logical to introduce the basics of complex exponential notations in Chapter 1, when the solutions to the wave equation are considered, rather than in this chapter.

In Chapter 3 the oblique incidence of plane sound waves on a layer of porous material is investigated. Both isotropic and anisotropic materials are considered. The locally reacting surface is defined in two ways so that: (i) surface impedance shows no angular dependence and (ii) response of a certain point on a surface is independent on the behaviour of other points. It would be helpful for some readers to show that these two definitions are related.

In Chapter 4 materials with identical cylindrical pores having different cross sectional shapes are investigated. These materials are considered as equivalent fluids with complex density and bulk modulus. Expressions for these quantities are derived assuming different cross sections and the important concept of hydraulic radius is introduced. The definition of tortuosity is given for materials with oblique straight pores.

In Chapter 5 the parameters employed in semi-empirical models of rigid frame porous materials are introduced. These are low and high frequency tortuosity, viscous and thermal characteristic lengths, and viscous and thermal permeabilities. A description of methods allowing their independent measurement is also provided. A critical analysis of various semi-empirical models with regards to their agreement with data given in this chapter is very useful as well as other practical considerations of their applicability. The second part of this chapter describes the basics of homogenisation theory in application to single and double porosity media. It is also stated that the modelling presented in Chapter 4 for materials with cylindrical pores is in line with the homogenisation procedure. This *a posteriori* justification is undoubtedly useful. However, the approach could be easier if homogenisation theory had been introduced prior to any microstructure-based models.

In Chapter 6 sound propagation in poroelastic isotropic materials is studied. A general quadratic form for the kinetic energy is introduced following the work of M. Biot, and expressions for the inertial forces acting on the frame and on the pore fluid are derived. Further, the wave equations are derived using the analogy between the stress–strain relations for the isotropic elastic solid and those introduced by Biot. The existence of two compressional and two shear modes is demonstrated. A further note about partial decoupling of two compressional modes in air filled porous material with stiff and heavy frame helps to understand the limitations of the rigid-frame models.

Equations are further derived for normal incidence surface impedance of a rigidly backed layer of porous material taking two compressional waves into account. The theory is compared with data where the resonance of a frame-borne wave is clearly demonstrated. In appendices to this chapter several alternative formulations of the Biot equations are presented.

In Chapter 7 sound radiation by a point source above a rigid-frame porous layer is considered. First, the wave reflected from a finite thickness porous layer is calculated using the method of steepest descent. The poles of the reflection

doi:10.1016/j.jsv.2010.04.019

coefficient are studied both in respect to plane waves associated with them and in respect of their contribution to the monopole pressure field. An expression for the reflected pressure field similar to that derived by Chien and Soroka in 1975 is presented as well as its simplified version. The applicability of the latter is thoroughly investigated and it is concluded that the simplified version is relatively accurate except for very thin layers with low flow resistivity when the wave incidence is close to grazing.

In Chapter 8 modes of air saturated porous frames are studied. Predictions of the frame displacements are made for excitation by an obliquely incident plane wave and by a normal stress field. Equations are derived for the surface impedance and reflection coefficient of a poroelastic layer with rigid backing. An integral representation of the frame velocity components is given for a circular source and for a line source excitation. Rayleigh wave excitation in a semi-infinite layer and modified Rayleigh wave in a finite thickness poroelastic layer are described. A dispersion relation is presented for an unloaded layer bonded on a rigid backing and its roots are found numerically for an example material. These solutions are compared to those for a free plate with doubled thickness. After that, the excitation of the resonances by a point source in air is considered and a good agreement is demonstrated between the data and the theory (although adjusted values of the shear modulus and Poisson ratio have been used in the latter). It is explained how these experiments can be used to estimate the material rigidity parameters in the audio frequency range.

In Chapter 9 sound absorption by porous materials with perforated facing is discussed. In addition to theory, examples are given to illustrate how the low-frequency absorption of porous layers can be improved using perforated facing. An excellent balance of the theory and its applications to absorber design is achieved in this chapter.

Chapter 10 introduces some approaches to modelling sound waves in transversally isotropic poroelastic media. It is started with derivations of the stress–strain relationships in such a medium. After that, dispersion relations are derived for waves polarised in a meridian plane and for those with polarisation normal to it. Partial decoupling of the waves in materials with heavy frame is discussed and is illustrated by an example. Sound propagation in a rigid-backed layer of transversally isotropic porous material is considered for two types of excitation: sound source above the layer and mechanical excitation at the surface. Some attention is given to the case when the symmetry axis does not coincide with the normal to material surface. A transfer matrix representation of transversally isotropic poroelastic medium is introduced at the end of this chapter.

This method is further used to model multilayered structures in Chapter 11. First, matrix representations of fluid, elastic and poroelastic layers are given. Two particular cases of the latter are considered next, namely limp porous material and rigid-frame material. Transfer matrices are derived for thin elastic plates and impervious screens. Assembling of the global transfer matrices is considered to represent the behaviour of multilayered structures. This procedure is illustrated by a number of examples.

Extensions of the transfer matrix method are discussed in Chapter 12. This includes finite absorber size corrections for both transmission and absorption problems. Numerous examples illustrate the method's extension for a structure-borne excitation. An excitation by a point source is briefly discussed at the end of the chapter.

In recent years, numerical methods have become increasingly popular in modelling sound absorbing materials. One of the most powerful techniques – the finite element method (FEM) – is described in Chapter 13. Amongst the examples considered are finite absorber size effects and damping effects of a plate–foam system. However, perhaps the most interesting examples are those illustrating the applications of FEM to modelling double porosity materials and smart foams.

All in all this is an impressive book which will serve as an excellent reference for those working in the acoustics of porous media, and as a perfect introduction to the subject for novices. Despite the emphasis on modelling techniques, a considerable number of examples and experimental results presented in the book make it useful reading for experimentalists as well as practitioners.

Olga Umnova
University of Salford, Salford, Greater Manchester, M5 4WT, UK
E-mail address: O.Umnova@salford.ac.uk