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Acoustic Propagation Constant at High Frequency from Modified Fluid Dynamic Equations

R. A. Piccirelli and K. H. Im
Mechanical Engineering Sciences
and Research Institute for Engineering Sciences Wayne State University, Detroit, USA

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Abstract

Data for the propagation constant of sound waves in rare gases are explained by using a set of integro-differential equations for the fluid dynamics variables. A simple model for the transport kernels is given.

Existing measurements of the complex propagation constant as a function of frequency in gases [1–7] are excellent and extend through the transition region where the mean free path is equal to the typical length of the phenomena under study, namely the wavelength.

It is well verified that the discrete modes predicted by the Navier-Stokes dispersion equation account for the data for $r > 0.5$ where $r = \upsilon_c/\omega$ (in which υ_c is a collision frequency) while for $r < 0.1$ a free-molecule kinetic approach can account for the data [1–7]. Until recently, however, it has not been clear how the correct limiting forms emerge from a single expression for the pressure perturbation [8, 9]. The most frequently used approach to providing a theory for all r including the transition range has been to use a kinetic theory, that is an approach in which the one particle velocity distribution is determined. Important progress was made by Buckner and Ferziger [10]. Their work demonstrates that a complete expression for the pressure which is in substantial agreement with the data can be derived from the first two of the BKG model kinetic equations.

In this note we describe work which supports both the validity and the utility of what can be called the "generalized fluid dynamics" approach [11–17]. Rather than resorting to a kinetic description in terms of the velocity distribution (which is in these experiments not measured), this approach uses a set of equations for the usual fluid dynamic variables which (a) consists of the same conservation equations, (b) uses the same equations of state and, (c) has the same boundary conditions as would be used in modeling the problem with classical fluid dynamics.