Integrating Acoustic Measurements of Sound Speed and Viscosity within a Re-entrant Cavity Resonator

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A re-entrant cavity, originally designed for microwave dielectric permittivity measurements, was modified for acoustic measurements of sound speed and viscosity in gases. Custom-made transducers were designed to excite a broad range of acoustic resonances to probe the different regions of the cavity. By modelling each resonance using Finite Element Analysis, a mode at 1000 Hz was found to be dominated by viscous losses and therefore suitable for measurements of viscosity, analogous to the Greenspan viscometer [1]. Within the scope of our study, the acoustic modes were experimentally investigated over a modest temperature and pressure range (305 K to 335 K with pressures up to 1 MPa) to obtain comprehensive data sets for the pure substances argon, nitrogen, and helium. After regressing the data to a simple linear model, kinematic viscosities were found to lie within 5 % of the predictions for each fluid using the reference viscosity correlations for each fluid implemented in REFPROP 9.1. A separate mode at 3400 Hz was used to determine speed of sound to within 0.5 %, from which density and thus viscosity were derived. This study has demonstrated that a re-entrant cavity can be used to determine viscosity and sound speed. Combining this promising technique with well-established microwave measurements using the same apparatus would allow a comprehensive determination of various thermophysical properties including dielectric permittivity, molar polarizability, density, viscosity, phase transitions, and liquid-volume fraction.

References:

[1] K.A. Gillis, J.B. Mehl, M.R. Moldover, Theory of the Greenspan viscometer. J. Acoust. Soc. Am. 114 (2003) 166-173.