Temperature variation of the acoustic properties of laboratory sediments

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Session W. Physical Acoustics IV: Miscellaneous

Robert E. Apfel, Chairman

Yale University, Mason Lab, 9 Hillhouse Avenue, New Haven, Connecticut 06520

Chairman's Introduction—2:00

Contributed Papers

2:05

W1. Sound propagation in colloidal suspensions in electrolytes. M. E. Gültepe, M. A. Barrett-Gültepe, and E. Yeager (Department of Chemistry, Case Western Reserve University, Cleveland, OH 44106)

The propagation of ultrasonic waves through colloidal suspensions in electrolytes is of interest from the standpoint of understanding sound propagation in the sea and in biological systems, and as a means for study of colloidal systems. Ultrasonic velocity and absorption measurements have been carried out in suspensions of particles of various configurations, including polystyrene latex (monodispersed spheres of, e.g., 5500 Å), kaoline (sodium form, platelets), montmorillonile (sodium form, platelets), and microcrystalline cellulose (rods) over a range of suspensions concentrations at several frequencies. The velocity changes associated with the colloid occur principally because of the difference in static adiabatic compressibility of the colloid phase and bulk electrolyte. With very small particle size—high surface area system, the change in compressibility of the solvent molecules adsorbed on the colloid surfaces may also be significant. The principal factors contributing to the additional absorption are relative motion losses, thermal conductivity across the interfaces, an ionic double layer, and adsorption-desorption relaxation. Particle-particle interactions must also be taken into account in the more concentrated suspensions. [Research supported by ONR.]

2:20

W2. Pulmonary ventilation by high-frequency oscillations. J. J. Fredberg (Cambridge Collaborative, Inc., Cambridge, MA 02142)

Bohn *et al.* [Fed. Proc. Fed. Am. Soc. Exp. **38** (3), 951 (1979)] reported that paralyzed beagle dogs maintained normal gas exchange for six hours or more when small oscillatory flows were maintained at the airway opening (15 cc tidal volume @ 15 Hz). These tidal volumes were 25% of pulmonary dead space and, thereby, were too small to permit convective gas exchanges with pulmonary airspaces. To test the hypothesis that effective gas exchange can be achieved by enhanced axial diffusion promoted by high-frequency oscillatory flows, I have modelled that process and computed the time constant for concentration equilibration in the lung as a function of flow amplitude and frequency. Knowing the distribution of oscillatory flows within the bronchial tree [Fredberg and Moore, J. Acoust. Soc. Am. **63,** 954-961 (1978)], the enhanced diffusion due to oscillatory flows [Chatwin, J. Fluid Mech **71,** 513-527 (1975)] may be integrated along the bronchial tree. The results indicate that gas concentration gradients within the lung can be substantially abolished within 10^{0} to 10^{-2} s. This suggests that diffusion enhanced by small-amplitude oscillatory flows (tidal volume $\ll$ dead space) can support effective gas exchange in the lung in the absence of convective transport (breathing). [Work supported by the Physicians' Service Incorporated Foundation, Ontario.]

2:35

W3. Sound velocity versus temperature measurements in tissues. Steven R. Jacobs, Douglas A. Christensen, Steven A. Rockhold, and Steven A. Johnson (Department of Bioengineering, 2059 Merrill Engineering Building, University of Utah, Salt Lake City, UT 84112)

We have developed a sensitive interferometric technique for measuring the variation of the velocity of ultrasound in tissue as a function of temperature. The tissue samples are placed between two transducers mounted in an invar holder, and this assembly is situated in a temperature-controlled water bath. The transmitting transducer is excited continuously by a crystal-controlled oscillator at a frequency of 10 MHz. The phase of the received signal is compared with the phase of the transmitted signal by a vector voltmeter. Variations in velocity are detected as changes in the relative phase between the transmitted and received signals. The overall accuracy of the system allows resolution to within 3° of phase difference. This corresponds to an accuracy of 10 ppm for a transducer spacing of 10 cm. The experimental data will be used in a larger project aimed at measuring internal body temperature nonintrusively with computer-aided tomography. Temperature resolution on the order of 0.1 °C across 1 cm of tissue are expected in the final instrument.

2:50

W4. Rectified diffusion in the presence of surfactants. L. A. Crum (Department of Physics, Oxford, MS 38677)

Measurements are reported of the growth of air bubbles by rectified diffusion in water at 22.1 kHz. Values were obtained of both the threshold and the rate of growth of bubbles by rectified diffusion as a function of bubble radius, acoustic pressure amplitude, liquid surface tension, and equilibrium gas concentration. Good agreement with theory was obtained for normal values of the surface tension of water for both the rectified diffusion threshold and the growth rate. With addition of a surfactant, measured values of the threshold and growth rate deviate from the calculated values, the disagreement becoming considerable at large surfactant concentrations (low surface tension). Surface-wave activity of the bubble that would increase the diffusion rate by acoustic streaming was not observed at low bubble radii and is not thought to be the cause of the disagreement. A possible explanation is given in terms of the retardation of gas diffusion by the surfactant monolayer on the surface of the bubble. [Work supported by the Office of Naval Research.]

3:05

W5. Temperature variation of the acoustic properties of laboratory sediments. Donald J. Shirley and David W. Bell (Applied Research Laboratories, The University of Texas at Austin, TX 78712)

The compressional wave speed and attenuation and the shear wave speed and attenuation of unconsolidated artificial laboratory sediments have been measured as a function of temperature. No overburden or pore pressure in excess of that found at a few centimeters depth was applied. The compressional wave speed of the sediment was found to vary approximately as would water with a slight increase in the slope of the curve of the sediment over that of water. Shear wave speed appears to be independent of temperature within the accuracy of the measurement. Attenuation of both types of acoustic waves also appears to be independent of temperature. [Work supported by the Office of Naval Research.]

3:20

W6. Visualization of acoustical processes in gases consisting of many interacting particles. Maria Heckl (Institut für Technische Akustik, Technische Universität Berlin, West Germany)

For most acoustical calculations the carrier of the sound waves (air, water) is considered to be a continuous medium. This, however, is oversimplifying as it is known a gas consists of particles which move with randomly distributed speeds and interact by many impacts. The intention of this paper is to visualize—with the help of a film—acoustical processes under these conditions. The particles are considered as totally elastic mass-points which hit together and exchange energy and momentum according to the well-known conservation laws. With this model some simple phenomena such as sound propagation, damping, and reflection will be discussed.

3:35

W7. Nearfield of ultrasonic transducer–lens systems: Theory with Gaussian–Laguerre formulation. Eduardo Cavanagh and Bill D. Cook (Cullen College of Engineering, University of Houston Central Campus, Houston, TX 77004)

Within the regions of validity of the Fresnel approximations, a Gaussian–Laguerre formulation permits rapid calculation of fields of transducer–lens systems. Separation of lens from the transducer is found to change significantly the structure of field. When the lens is at a focal length from the transducer, the field is found to be symmetric with respect to the focal plane. The asymmetry when the lens is not at this distance depends on the location of the lens and the ratio of the focal length to the length of the nearfield.

3:50

W8. Nearfield of ultrasonic transducer–lens systems: Comparison of experiment and theory. P. L. Edwards (Department of Physics, University of West Florida, Pensacola, FL 32504), Bill D. Cook (Cullen College of Engineering, University of Houston Central Campus, Houston, TX 77004), and Henry D. Dardy (Naval Research Laboratory, Washington, DC 20375)

Local acoustic pressures in the nearfield of ultrasonic transducer–lens systems were determined by measuring the scattering from a microsphere scanned through the field. The lens was placed both adjacent to and separated by a distance of one focal length from the transducer. Typical parameters were the following: frequency 5.0 MHz, transducer diameter 0.5 in., focal length 1.0 in., diameter of microsphere 0.002 in. Experimental results show remarkable comparison with the details predicted by the Gaussian–Laguerre formulation presented elsewhere in this meeting. [This research was conducted at the Naval Research Laboratory, Physical Acoustics Branch, Washington, DC.]

4:05

W9. Studies of acousto-optic interactions in optical fibres. E. F. Carome, K. P. Koo, and P. B. Schmidt (John Carroll University, Cleveland, OH 44118)

Studies are continuing of acoustically induced phase and intensity modulation of light beams propagating in optical fibres. A fibre element submerged in water is irradiated with plane acoustic waves. The optical field exiting from the output end of the fibre is precisely scanned. Acoustically induced changes in the output pattern are being examined in an effort to obtain information on fibre mode–mode coupling and other phenomena. Details of the measurements and recently obtained experimental results are presented. [Work supported in part by ONR.]

4:20

W10. Acoustic emission from leaking values. J. W. Dickey (David W. Taylor Naval Ship Research and Development Center, Annapolis, MD 21402)

The acoustic emission associated with leakage through air, steam, hydraulic, and water valves has been investigated. Experiments were performed to determine what characteristics of the acoustic emission may be related to leak rate with the hope that instrumentation could be developed to acoustically detect and measure leakage. The spectral and temporal characteristics of leakage-associated signals taken from externally mounted detectors or valves indicate that average acoustic amplitude in selected frequency ranges provide a useful measure of valve leakage for most styles of air, steam, hydraulic, and water valves. The existence of cavitation in water and hydraulic fluid complicates leakage measurement and, for hydraulic fluid, the sum of event amplitudes multiplied by their rate of occurrence results in a value which increases with increasing leak rate. The data collection and analysis used to support the conclusions are discussed.

4:35

W11. A versatile fast scanner for ultrasound temperature tomography and wide aperture synthetic focus imaging. Steven A. Johnson (Department of Bioengineering, University of Utah, Salt Lake City, UT 84112), Allen R. Grahn, Charles D. Baker (UBTL Division of the University of Utah Research Institute, University of Utah, Salt Lake City, UT 84112), George Randall (Department of Computer Science, University of Utah, Salt Lake City, UT 84112), Douglas A. Christensen, Steven R. Jacobs, and Michael J. Berggren (Department of Bioengineering, University of Utah, Salt Lake City, UT 84112)

A versatile laboratory scanner of modular design is described which can support a wide variety of ultrasound transducers and transducer arrays. The basic design consists of a rotating platform on which are mounted various types of interchangeable, temperature regulated water tanks. The platform is rotated in 0.02° steps by a high torque stepping motor. Various transmitter and receiver geometries or configurations are arranged in each water tank. One tank configuration uses spherical or cylindrical acoustic waves and a curvilinear, circular receiver array for high speed (1 to 10 s) data collection for reconstruction of tissue temperature. This method makes use of acoustic refractive index reconstruction tomography and the temperature dependence of the acoustic refractive index. This tank configuration also permits the use of microwave or high-power, focused ultrasound beams for tissue heating while simultaneously reconstructing the temperature of the tissue samples. A second tank configuration uses plane waves and a rectilinearly scanned receiving array for diffraction tomography studies. A third tank configuration permits the use of a new high resolution reflection or scattering imaging technique now known as either "synthetic focus imaging" or "reflection tomography." [Supported by NIH grants NCI IR01 CA 23430 and H2-00170 and PDP-110 from American Cancer Society.]