SHAPE OSCILLATIONS OF BUBBLES IN WATER AND INFLUENCES PERTINENT TO SUCH OSCILLATIONS

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The shape oscillations of acoustically levitated bubbles were used to probe the interfacial rheology of bubbles in clean water and in sea water and in water containing surfactants. Clean water conditions produced agreement with an improved theoretical analysis while bubbles in sea water displayed an excess damping. A new method was demonstrated for injecting a known amount of insoluble surfactant onto an acoustically levitated bubble. The method was used to test an analysis of the increase in damping and the shift oscillation in frequency resulting from the modification of the interfacial rheology. Analysis of CCD images of pendant bubbles was used to monitor the evolution of the surface tension resulting from surfactants injected onto a pendant bubble.
I. Research Summary

A. Project Goals:

We wished to understand aspects of the dynamics and evolution of small bubbles in water. The emphasis was on the measurement of shape oscillations as a probe of the bubble’s surface in distilled water and in sea water. The oscillations are influenced by surface active materials present (or injected into) the water samples. Monitoring the frequency and decay rate of shape modes over an extended period of time (along with the size of the bubble) allows the evolution of the surface properties to be inferred. The measurements are also relevant to understanding the nonlinear dynamics of bubbles. The evolution of surface properties was also inferred by monitoring the shape of pendant bubbles.

B. Results:

The most significant results pertain to the influence of surfactants on the dynamics of bubbles in clean (fresh or salt) water and in sea water. Bubbles acoustically levitated in purified fresh and salt water had a decay rate and frequency for shape modes in agreement with a theory that took into account the viscous dissipation in the outer fluid (water) and in the inner fluid (air) for the case of an ideal interface. Bubbles in natural sea water always displayed significant excess damping and a shift in frequency from the predicted results for pure sea water. It should be noted however, that only a few sea water samples were studied and these all came from the same location in Puget Sound. The excess damping can be attributed to the presence of natural surfactants in the sea water as evident from the controlled experiments with surfactants on bubbles in fresh water summarized below.

The surfactants of interest can be roughly put into either two categories according to their solubility: (i) surfactants which are sufficiently insoluble that there is negligible loss or gain of surfactant molecules from the surface of a bubble under normal conditions and (ii) surfactants that are sufficiently soluble for significant diffusion to or from the surrounding water. While both (i) and (ii) clearly gave excess damping in sufficient concentrations, the best comparisons with theory were possible for insoluble surfactants since a novel method was developed for injecting a controlled amount onto the surface of an acoustically levitated bubble. As gas dissolved, the surface area of the levitated bubble decreased, producing a known increase in surface concentration. The resulting evolution of the shape oscillation damping rate and frequency was in agreement with a model of the interfacial rheology when interfacial parameters were adjusted to be within physically reasonable values. Analysis of CCD images of pendant bubbles was used for case (i) to monitor the evolution of the surface tension or spreading pressure.

Supporting research includes experiments performed on the Space Shuttle in 1992 which clarified the proper size range for studying bubble dynamics on the earth, quantitative studies of the effects of acoustic radiation pressure on bubble dynamics, and novel optical methods for detecting bubble oscillations.
II. Students supported or partially supported by this grant:

   M.S. Report title: Studies of Acoustically Levitated Air Bubbles in a Water Filled Rectangular Chamber
   Ph.D. Thesis title: Shape Oscillations of Bubbles in Water Driven by Modulated Ultrasonic Radiation Pressure and Applications to Interfacial Dynamics

B. Other graduate students partially supported with this grant:
   (b) Scot F. Morse (M.S. completed: 1994, Ph.D. thesis work in progress)
   (c) Mark J. Marr-Lyon (M.S. completed: 1995, Ph.D. thesis work in progress)

C. Undergraduate student partially supported: Nathaniel Hicks (B.S. in Physics in progress)

D. Postdoctoral Assistant partially supported: David B. Thiessen

III. Publications and Reports

A. Peer Reviewed Publications:


B. Other Publications in Preparation:


C. Conference Publications


(1995). [Invited presentation at the American Association of Physics Teachers Summer Meeting.]* + **


14. Thiessen, D. B., Marston, P. L., and Asaki, T. J., Modification of bubble properties by direct injection of insoluble surfactants and other advances in bubble dynamics (abstract at press); to be presented at the 132nd meeting of the ASA.

E. Other Reports:

An Annual Report is published for each grant year in the ONR Ocean Engineering and Marine Systems Program (ONR 321) compilation of research abstracts.

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