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Proceedings of the Underwater Acoustics Group, Institute of Acoustics

HIGH-SPEED PHOTOGRAPHY OF LASER-INDUCED BREAKDOWN IN LIQUIDS

by

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INTRODUCTION

This contribution was based on a movie film supplied by Dr Lauterborn. The film consists of a series of short clips of high-speed movie shots of bubbles oscillating in various environments.

The experimental set-up consisted of a small rectangular tank with transparent sides. The cavities were generated by an intense beam of light from a pulsed ruby laser. In this way, existing small air nuclei were expanded to a diameter of a few mms and allowed to collapse and rebound under the existing ambient pressure. The cavities therefore contained a mixture of air and liquid vapour. The liquids used were water and silicon oils of two viscosities, 5 and 10 Poises. Afast rotating-mirror camera was used to take the pictures, at speeds of 75 000, 275 000 and 305 000 frames per second.

The first shot showed a single bubble generated in water, free of boundaries and other bubbles. In this case, the surface of the bubble distorts during, or immediately after, the first rebound. In the next two shots, the liquid medium is silicon oil, viscosity 5 and 10 poises. In this case, several oscillations of the bubble are obtained before the motion damps out, and the spherical shape is retained throughout the motion. In these, the initial collapse is clearly no longer transient, due to the heavy damping imposed by the high viscosity.

In all of the other shots, water is used as the medium. Bubbles are generated near a rigid boundary. On the first collapse, a liquid jet is formed and projects towards the surface. On rebound, frequently a reverse-jet is produced, projecting away from the surface. The bubble then generally disintegrates. For the jet to form the bubble must collapse at a distance of not more than a few radial distances from the surface. A slow-motion run showed detail of the jet and counter-jet formation.

The last few shots showed bubbles interacting with one another. Two bubbles of similar sizes will attract and coalesce. Bubbles of widely-different sizes will not coalesce, but the smaller of two interacting bubbles will develop jets, towards and away from, the larger one.

DISCUSSION

For the freely-oscillating single bubbles it is possible to plot radius-time curves using measurements taken from the movie. These can be compared with theory. Dr Lauterborn used the "incompressible" theory with the addition of a term which expresses the effect of viscosity, and found good agreement.

Dr Safar asked about the practical significance of the work. The violent jetting which takes place near surfaces is now known to generate stresses in the surface capable of producing erosion pitmarks. These stresses can be estimated approximately from the measured jet speed along with a knowledge of the characteristic impedances involved. Dr Morch wondered whether the impact stresses would be affected much by taking into account the effect of the free gas in reducing the effective impedance of the liquid.

Dr Crum mentioned that Professor Plessett (CalTech) has evolved a theory to account for the jetting, which does not, however, explain the counter-jetting.

There was active discussion and argument about the actual composition of the jets and about the gas-content of the bubble when jetting occurred. In one of the movie shots, the jet can be seen breaking up into a succession of small bubbles. It seems clear that the original air nucleus has accumulated a good deal of permanent gas as well as vapour during its growth. The core of the jets is almost certainly gas, but sufficient liquid is drawn down to the solid surface at high speed to initiate erosion damage.

Bubbles must approach one another to within a few radial distances be fore interaction can occur. Considering the very small sizes of bubbles involved in ultrasonic cavitation, it remains uncertain how much jetting of the sort seen in the movie could take place.