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Response of rising bubbles to a sudden depressurization

C. D. Ohl and A. Prosperetti*
Department of Applied Physics, University of Twente, Enschede, The Netherlands
Email: c.c.m.rindt@wtb.tue.nl
*Also: Department of Mechanical Engineering, The Johns Hopkins University, Baltimore U.S.A.

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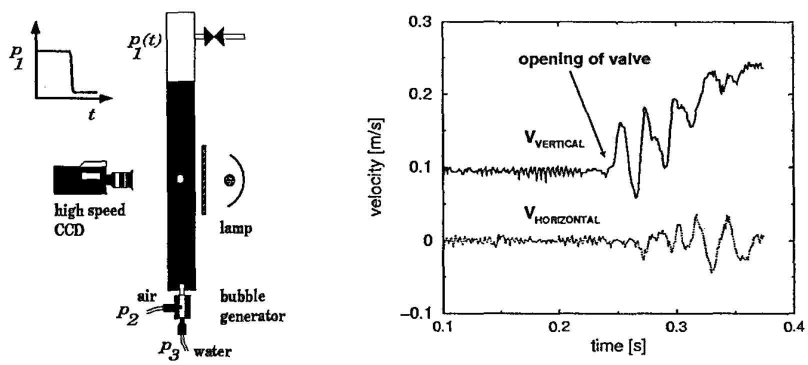
Abstract - The response of single rising bubbles in a stagnant pressurized vertical tube is investigated experimentally. The bubble is subjected to a rapid depressurization from a few atmospheres to ambient pressure. The translational and radial dynamics are recorded by means of high speed video and analyzed with digital image processing techniques. In particular, the onset and the frequency of the radial oscillation and its coupling to the translational acceleration are investigated. Additionally, the onset of path instabilities which are triggered by the volume increase are considered. The observed bubble behavior is compared to a model taking into account buoyancy, added mass and the drag forces. The bubble dynamics is recorded at a speed up to 2000 frames/s with a CCD camera (Kodak HG2000, 512 × 384 pixels). The pictures are transferred to a computer for digital image processing. The steps consist of edge detection, thresholding and tracking of closed contours. From the contour data, the diameter and centroid are calculated. This makes it possible to track the shape, size and position of the bubble without user intervention. Depending on the rise velocity of the bubble (determined by the bubble size), and the magnification used, the bubble can be tracked for several hundred pictures.



The experimental set-up (left) and the vertical and horizontal velocity component of a rising bubble subjected to a pressure change from $p_i = 4\,bar$ to $p_f = 1\,bar$. (right)

This experiment allows one to vary the bubble volume by decreasing the pressure from p_i to p_f during the rise. Assuming a slow volume change (compared to the natural frequency of the bubble) the bubble radius will increase from a smaller initial radius R_i to a larger radius $R_f = R_i \sqrt[3]{p_i/p_f}$, neglecting surface tension. It is known that in water bubbles smaller than 0.7 mm in radius rise rectilinearly, while larger bubbles exhibit a zig-zag or spiraling motion. The experimental setup allows to investigate the onset of the spiraling motion as a consequence of the volume increase. As shown in the Figure at time $t = 0.24\,\mathrm{s}$, the valve is opened and due to the volume increase the bubble is accelerated upwards; 20 ms after the pressure decrease the bubble shows a non-zero horizontal velocity and a transition to a zig-zag motion. These first experimental results suggest that it will be possible to investigate in detail the response of bubbles for Reynolds numbers between 100 to 1000.

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