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ORIGINAL PAPER

Asymmetric deformation of bubble shape: cause or effect of vortex-shedding?

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Two perpendicular projections of rising bubbles were observed in counter-current downstream diverging flow. Evidently, the bubbles did not enter the boundary layer at the channel wall and a plug liquid flow assumption was acceptable in our experimental equipment. This confirmed that the experiment was appropriate for simulation of bubble rises in a quiescent liquid column. Recent data obtained by a high-speed camera permitted recording over a period of 60 s. Image analysis by a tailor-made program provided a time-series of quantities related to the position, size, and shape of bubbles. In addition to determination of the aspect ratio of the equivalent oblate ellipsoid, deviation from this shape was investigated in respect of the difference between the bubble's centre of mass and the geometrical centre of bubble projection. Autocorrelation of the data indicated that the bubble inclination oscillated harmonically with a frequency of 5–10 Hz; cross correlation showed that the horizontal shift of the centre of mass, as well as the horizontal velocity, increased with increasing bubble inclination, and the vertical shift of the centre of mass increased with an increases in the absolute value of the bubble inclination. There is no significant phase shift in the oscillation of these quantities. The bulky bottom side of the bubbles is in accordance with the model of bubble oscillation induced by instability of the equilibrium of gravity and surface tension forces. The oscillation frequency dependence on surface forces (Eötvös number) is evident, while viscosity does not play a significant role in low-viscosity liquids. Therefore, vortex-shedding is more likely to be an effect of the oscillation and not its cause.

Keywords: bubble, bubble shape, bubble velocity, bubble oscillation, surface tension

Introduction

Medium-size bubbles rising in low-viscosity liquids are non-spherical bodies. Usually, the bubble shape is approximated by an oblate ellipsoid; the typical shape is presented in Fig. 1.

The trajectory of larger bubbles rising in liquids is not a straight vertical line. It has an apparently helical or zigzag pattern. Prosperetti (2004) noted that this behaviour had previously been noted in the notebooks of Leonardo da Vinci (Project Gutenberg, 2010) and introduced the term "Leonardo's paradox".

The shape of medium-size bubbles is similar to an oblate ellipsoid. A bubble wobbles and its drift velocity u_x is oriented towards the other side than that for solid bodies of a similar shape. As the rising velocity of medium-size bubbles in water is 0.2–0.3 m s^{-1}, the bubbles can be traced in a stationary column for a short time-period only. Therefore, quantitative data related to the shape and size of rising bubbles were limited. The essential qualitative description of the bubble motion was noted by Saffman (1956). Pioneering experimental studies of small bubbles were performed by Aybers and Tapucu (1969a,

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