ISSN 0973-8975

J.Mech.Cont.& Math. Sci., Vol.-9, No.-2, January (2015) Pages 1397-1403

EXPERIMENTAL STUDY ON SHAPE AND RISE VELOCITY OF SMALL BUBBLES IN STAGNANT WATER

By

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Abstract:

This paper presents the results of an experimental study on the shape and rise velocity of small bubbles rising in stagnant water. Bubbles, generated at the bottom of the chamber holding water, rise through it. A high speed camera (1000 fps, Kodak, Model 1000 HRC) together with a 90 mm Macro lens is placed at a height of 60 cm from the bottom of the chamber. It is linked with a PC. The commercial software SigmaScan Pro 5.0 and Adobe Photoshop are used for image capturing and processing. Bubbles (diameters in the range 0.0245-5.903 cm) are generated at the bottom of the chamber holding the water. We find that bubbles have three steady shapes, a sphere, an ellipsoid and spherical cap in this diameter range. The experimentally determined rise velocity of bubble in the present investigation agrees well with the data available in the literature.

Keywords and Phrases : *Bubble, Shape, Rise Velocity, Stagnant Water*

1 Introduction.

Air bubbles rising in water may be widely observed in many industrial processes. Examples in chemical engineering include bubble columns, loop reactors, agitated stirred reactors, flotation, and fermentation reactors [1-11] . For the design of efficient two-phase reactors, detailed knowledge of bubble sizes and shapes, rise velocities, internal circulation, swarm behavior, bubble induced turbulence and mixing, and bubble size distribution (including coalescence and breakup) is of fundamental importance. So an understanding of the bubble characteristics will help the various hydrodynamic phenomena occurring in the industrial bubble column.

Bubble Shape**:** Normally, a bubble at rest assumes a spherical shape because surface tension minimises surface area for a given volume. Bubbles in free rise in infinite media by gravity are generally grouped into three categories based on its shape, as shown in Fig 1 [12]:

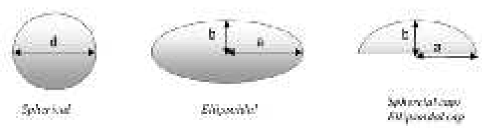

Fig 1 Categories of bubbles based on shape

A rising bubble is described by its rise velocity, shape and motion behaviour. All three features are linked with the physical properties of the system, in particular the viscosity of the liquid phase, the flow and the interfacial bubble particularities (given by the possible presence of surfactants).

For bubbles rising freely in infinite media a graphical correlation [Fig 2] is developed by Grace et al. [13,14] in terms of the Eötvös number, Eö; Morton number, M; and Reynolds number, Re. This map is helpful in measuring the shapes of rising bubbles in Newtonian liquids, based on visual observations but perfect predictions are not possible to obtain from it. Therefore, an experimental study on the rise of the bubbles in stagnant fluid may be a starting point.

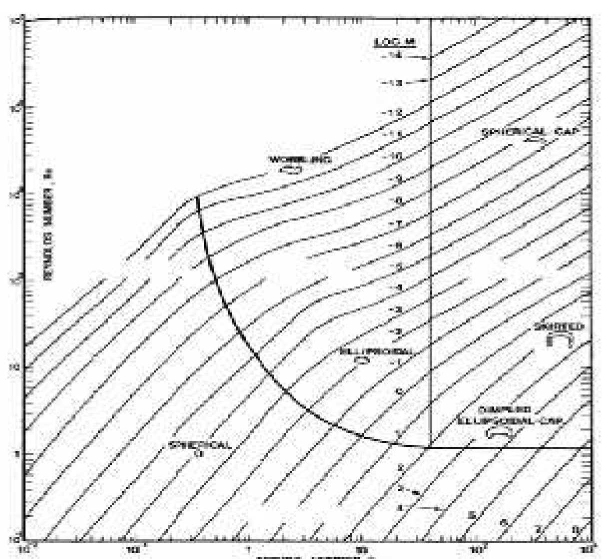

Fig 2 Shape regimes for bubbles

In the present investigation, experimental studies have been conducted in stagnant water in a vertical rectangular chamber. Bubbles are generated at the bottom of the chamber. Their shape and rise velocity are analyzed using video-image analysis.

2 Experimental Setup.

The experimental set-up is shown in Fig.3. Experiments are carried out in an open top polycarbonate chamber having dimensions 34 cm × 28 cm × 200 cm (length, width, height) [15-19], which is large enough to neglect the wall effects. The chamber is filled with water. Bubbles, from the compressed air mains, are successively generated through an orifice, placed at the centre of the bottom of the column. The size of the bubbles and its frequency of generation are adjusted by flowmeters. A high speed camera (1000 fps, Kodak, Model 1000 HRC) together with a 90 mm Macro lens is placed at a height of 60 cm from the bottom of the chamber. It is linked with a PC. The commercial software SigmaScan Pro 5.0 and Adobe Photoshop are used for image capturing and processing. With this setup, we study the shape and rise velocity of bubbles rising through stagnant water.

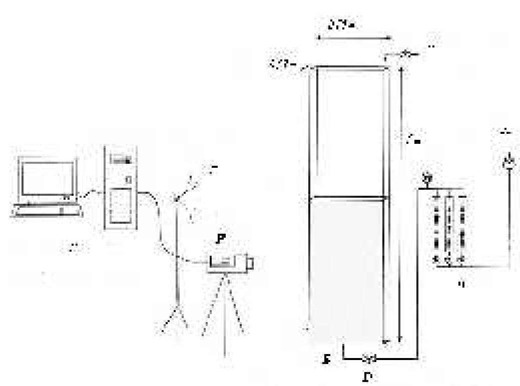

Fig 3 Experimental Apparatus

A: Compressed air, B: Rotameters, C: Water supply, D: Valve, E: Orifice injection, F: Video camera, G: Halogen lamp, H: Image capturing & processing PC

3 Results and Discussion.

3.1 Bubble shape and diameter

The still images, captured by the camera, are analyzed by PC using the commercial software SigmaScan Pro 5.0 and Adobe Photoshop to determine the bubble shape (height and width).

The bubble equivalent diameter d_{eq} is calculated as shown in Fig 4 [20]:

$$d_{eq} = (d_h \times d_w)^{1/3}$$

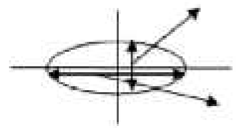

Fig 4 Bubble major and minor axes

The measured values of the equivalent diameters of the bubbles are in the range 0.0245-5.903 cm. We find that bubbles have three steady shapes, a sphere, an ellipsoid and spherical cap in this diameter range.

3.2 Bubble Velocity.

The concept of the terminal velocity of a rising bubble is, to some extent, vague, as the forces (Archimedian force, the drag, the lift and the virtual mass forces) exerted on the bubble never balance each other. So the bubble motion always remains unsteady. However, if the bubble motion is considered in an infinite fluid-medium, after some period of time we may speak of a certain average “rise velocity”, whose change in time can be neglected. The averaging is meant here over a time interval much shorter than the period of time passed since the beginning of the bubble motion. Therefore, under the terminal velocity we understand such a time-averaged (“smoothed”) rise velocity of the bubble.

Bubble velocity is determined from the video images of the bubble. Once the bubble is released, the video camera moves up with the bubble recording the images as it rises through various markers which are positioned at an interval of 15 cm from the bottom to a height of 1.8 meter. Velocity is measured for a 15 cm distance and is averaged for the entire 0.75 meter travel from 1.05 to 1.80 m along the scale.

The measured values of rise velocity of air bubbles (for various values of equivalent diameter) rising in stagnant water are presented in Figure 5 as a function of the bubble size. These data match well with those available in the literature [21, 22].

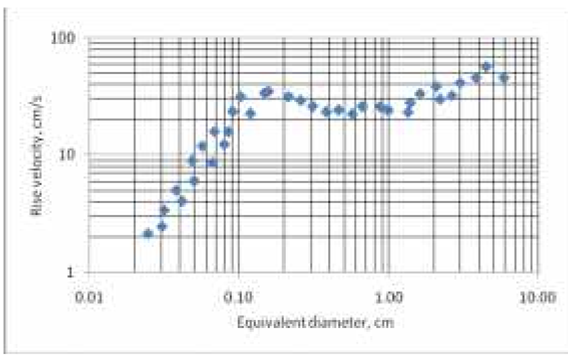

Fig 5 Variation of rise velocity with equivalent diatemetr

4 Conclusion.

In this experimental study, we report a video-image analysis on the shape and rise velocity of bubbles in stagnant water. A high speed camera (1000 fps, Kodak, Model 1000 HRC) together with a 90 mm Macro lens and the commercial software SigmaScan Pro 5.0 and Adobe Photoshop are used for image capturing and processing. Bubbles are generated at the bottom of the chamber holding the water. With this arrangement, bubble rise characteristics, namely, bubble shape and rise velocity are determined. The measured values of the equivalent diameters of the bubbles are in the range 0.0245-5.903 cm. We find that bubbles have three steady shapes, a sphere, an ellipsoid and spherical cap in this diameter range. The experimentally determined rise velocity of bubble in the present investigation agrees well with the data available in the literature.

References

1) Arnold, K. and M. Stewart, Surface production operations. 3rd ed. Vol. 1. 2008, Amsterdam: Elsevier. 768 p.

2) Speight, J.G., The chemistry and technology of petroleum. 1999, New York: Marcel Dekker. xiv, 918 p.

3) Haugan, J.A., Challenges in heavy crude oil - Grane, an overview, Journal of petroleum technology, 2006. 58(6): p. 53-54.

4) Bybee, K., Production of heavy crude oil: Topside experiences on Grane, Journal of petroleum technology, 2007. 59(4): p. 86-89.

5) Abdel-Aal, H.K., M. Aggour, and M.A. Fahim, Petroleum and gas field processing. 2003, New York: Marcel Dekker. XII, 364 p.

6) Shoham, O. and G.E. Kouba, State of the art of gas/liquid cylindrical-cyclone compact-separator technology, Journal of petroleum technology, 1998. 50(7): p. 58-65.

7) Baker, A.C. and J.H. Entress, The VASPS subsea separation and pumping system.Chemical engineering research & design, 1992. 70(1): p. 9-16.

8) Cohen, D.M. and P.A. Fischer, Production systems hit the seafloor running, World Oil, 2008. 229(1): p. 71-8.

9) CDS engineering and FMC Technologies, CDS StatoilHydro Degasser. [cited 2009 March 23]; Available from: http:// www.fmctechnologies.com/upload/ factsheet_cds_degasser.pdf.

10) Schinkelshoek, P. and H.D. Epsom, Supersonic gas conditioning - Commercialisation of Twister technology, in GPA conference. 2008: Grapevine, Texas, USA.

11) Gjerdseth, A.C., A. Faanes, and R. Ramberg. The Tordis IOR Project, in Offshore technology conference, 2007. Houston.

12) Clift, R., J.R. Grace, and M.E. Weber, Bubbles, drops, and particles. 1978, New York: Academic Press, xiii, 380 p.

13) Grace, J.R., Shapes and velocities of bubbles rising in infinite liquids, Transactions of the Institution of Chemical Engineers, 1973. 51(2): p. 116-20.

14) Grace, J.R., Shapes and velocities of single drops and bubbles moving freely through immiscible liquids, Transactions of the Institution of Chemical Engineers, 1976. 54(3): p. 167-173.

15) A. Mitra, T K Dutta & D N Ghosh, Natural Convective Heat Transfer in Water Enclosed Between Pairs of Differentially Heated Vertical Plates, Heat and Mass Transfer, 45, 2008, 187-192.

16) A. Mitra, T K Dutta & D N Ghosh, Augmentation of Heat Transfer in a Bubble-agitated Vertical Rectangular Cavity, Heat and Mass Transfer, 48, 2012, 695-704.

17) Mitra A, Bhattacharya P, Mukhopadhyay S, Dhar K K, "Experimental Study on Shape and Path of Small Bubbles using Video-Image Analysis," 2015 Third International Conf. On Computer, Communication, Control And Information Technology, 7 – 8 February 2015, Academy of Technology, Hooghly, West Bengal, India

18) S. Mukhopadhyay, N.K.Das, A.Pradhan, N.Ghosh, P.K.Panigrahi, "Wavelet and multi-fractal based analysis on DIC images in epithelium region to detect and diagnose the cancer progress among different grades of tissues", SPIE Photonics Europe-2014, Belgium.

19) S.Mukhopadhyay, N.K.Das, A.Pradhan,N.Ghosh, P.K.Panigrahi, "Pre-cancer Detection by Wavelet Transform and Multi-fractality in various grades of DIC Stromal Images", SPIE West Photonics-2014, USA.

20) Lima Ochoterena, R. and Zenit, R., 2003, Visualization of the flow around a bubble moving in a low viscosity liquid, Revista Mexicana De Fisica 49, 348-352.

21) R. C. Clift, J. R. Grace and M. E. Weber, Bubbles, Drops, and Particles, Academic, New York, 1978.

22) Zheng, Li and Yapa, P.D., Buoyant Velocity of Spherical and Non spherical Bubbles/Droplets, Journal of Hydraulic Engineering, Vol. 126, No. 11, 2000.