Experimental Analysis of Multiple Air-Bubbles Rise in Water Channel Using A Submerged Needle

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ABSTRACT

This paper studies the ascent of multiple air bubbles experimentally utilizing a high-framerate camera (HSC) (400 fps) which has the ability to capture fast moving objects which can then be played back in slow motion. Experiments conducted previously suggested that small air bubble pursues a rectilinear rise motion. Bubbles that have radius less than 0.81 mm approximately follow rectilinear path as concluded by [1] [2]. Notwithstanding, in the present study it has been seen that by utilizing a needle inside the water channel, multiple bubbles pursue a spiral movement in a path rather instead of a rising in a straight line. Motion is studied in both of these planes (X-Y and Y-Z). Image processing techniques have been utilized thus to upgrade the quality of the images and along these lines to examine the flow features of the multiple air bubbles rising in water.

Keywords:
High-speed camera (HSC), Image processing techniques, fps

1. Introduction

The movement of air bubbles through channels, funnels and tubes have been studied widely for numerous experimental, numerical as well as theoretical studies owing to their uses, varying from microscale to macroscale streams, for instance, thermos-siphons for cooling of electronic components, blending in microfluidics, biological applications, micro heat pipes, chemical reactors, etc. [3-5].

Other significant utilizations of air bubble ascending in channels incorporate blending layers, flotation cells, heat transfer in capillary tubes etc. Gravitational force is less as compared to surface tension force in microscale flows. Notwithstanding, gravity is substantially more essential in large-scale systems.

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Inferable from this, number of researchers have investigated the rise of bubbles and drops because of buoyancy which is there in the vertical channels and pipes [6] and in unbounded domains [7-8]. Gas infusion is additionally appealing which is a pumping mechanism for metals in liquid form in accelerator driven systems (ADS) [9], which is very useful for profoundly efficient power generation and for the change of radioactive waste [10]. Air-water two phase flow is also used as bubbly flow to isolate solid-solid particles. This process helps in extracting the minerals in mineral processing and flotation cells.

In the above discussed examples distribution of bubbles, their sizes and trajectories are of vital importance in order to control the flow. The behaviour of bubble’s rise solidly relies upon the size of the bubble and other characteristics of liquid and gas, for instance surface tension, density, viscosity [11].

The motion of the air bubbles has been widely examined experimentally, numerically and also hypothetically. Bubbles with a diameter of 0.7 mm were examined to give a sphere like shape and follows a linear ascent in water [12]. Notwithstanding, bigger sized bubbles exhibit an ellipsoidal or wobbling or shading shape and pursue a helical or a zig-zag random trajectory [13-14]. Maxworthy et al [15] worked on an ultraclean liquid. They showed that contaminated liquids have a crucial role in transformation of straight moving, spiralling, zigzagging bubbles trajectory.

A.W.G. de Vries [16] investigated and examined the path in which free bubble rises along with its wake in ultrapure water. The wake of bubble has an important and crucial part in understanding rising path of a specific bubble. A double-threaded wake is observed when the bubbles follow a non-rectilinear movement. The lift force of the bubble is responsible for spiralling and zigzagging of the bubbles. Bubbles in the range of 0.81-0.88 mm and 1.00-1.10 mm were found to be zigzagging mostly.

Saffman [12] performed experimental investigations on bubbles that have radius in the range from 0.4 to 1.1 mm. The air bubbles displayed a sensible transformation from rectilinear rise to spiral or zigzag ascent. This type of transformation occurred for bubbles with radius being 0.81 mm. The moment the changeover occurred, both zigzagging as well as spiralling bubbles were observed. In addition to this he also observed that if the radius is less than 0.7 mm, the bubbles then follow a rectilinear motion. Zigzag path was followed by bubbles with a radius of 1 mm and for bubbles having a radius of greater than 1 mm, zigzagging as well as spiraling both were noticed.

Small bubble however pursues a rectilinear ascent. Bubbles moves rectilinearly if their radius is less than about 0.81 mm as experimented by [1-2].

P. Hanafizadeh et al [17] experimented on the order of flow of air in water in a two-phase flow utilizing a high-FPS camera that is 1200 fps in vertical small pipe. To acquire clear and enhanced images of the bubble regimes, image processing techniques were performed. These techniques help in enhancing the quality of the images and thus post processing and further analysis is then performed with ease, for instance measuring perimeter of the bubble, area, diameter, velocity calculation etc.

2. Methodology

The experimental setup comprises of an open transparent prismatic vessel fabricated of acrylic glass. The length of the vessel along horizontal (x-axis) is 80 mm, along vertical (y-axis) is 200
mm, along z-axis is 80 mm. An opening of 2 mm is penetrated in the centre of the water tank. An air injector having a length of 30 mm is installed inside the water channel through this hole which then acts as the submerged needle. To infuse air inside the water channel using air injector an air storage is utilized. For recording a crystal-clear footage of the air bubbles motion in water, digital high-speed camera along with two light sources is used.

The dimensions of the water channel are depicted in Figure 1. The dimensions of the air injector are depicted in Figure 2 and Figure 3 presents the Experimental Apparatus used for performing the experiments.

Fig. 1. Dimensions of Water Tank

Fig. 2. Dimensions of Air Injector
The water channel is topped with water that is 180 mm high. Air is actually in the gaseous form and water is in liquid phase. First the air is infused into the water channel by utilizing the storage of air using the air injector. Images taken from two planes (x-y, y-z) respectively and are obtained utilizing the high-speed camera, in order to examine the flow features of the bubbles accurately. A video is filmed for 20 seconds that gives us the path of the bubbles from the perspective of x-y axis. Camera is then repositioned along the plane y-z. Then another 20 seconds video footage is made the gives us the pathway of the rise in bubbles correctly. In order to examine the flow features of the multiple air bubbles, the recorded film is then replayed and is converted to discrete frames in a pictorial format using Frame Shots Video Image Capture software. The acquired pictures are then used for performing image processing methods for desired results.

3. Results and Discussions

To examine the flow features of multiple air bubbles from the images obtained, it is quite important to play out some image processing techniques. These pictures have an 8-bit RGB colours, which is changed over from RGB to grey scale mode. This yield pictures that has 256 shades of grey scale intensities that ranges from 0 that is black colour to 255 which represents white colour. It is exceptionally hard to take out the bubble features form the original picture directly and consequently some pre-processing methods are to be performed to lessen distortion and increase the images clarity [17].

The pictures are initially transformed to gray scale from RGB. Then using threshold segmentation, the images are transformed to binary mode which is quite a useful technique of image segmentation and is very helpful in creating binary images from gray scale images. Air bubbles images of the two-phase flow are cleared by applying some image processing techniques in MATLAB. These techniques are additionally helpful in setting up the bubbles for quantitative analysis, like analysing trajectory, calculating area, diameter, perimeter etc.
3.1. Multiple Air Bubbles Rise

3.1.1. X, Y Plane

With the help of a controlled flow rate multiple these air bubbles were injected into water channel, shown in Figure 3 (a-c). The frame rate of the obtained images was kept to 20 frames per image. It is clearly visible in the below figures that row of bubbles follows a spiral rise rather than a rectilinear ascent. Figure 3 (d-f) depicts the rising path of the bubbles. Here the yellowish line indicates the spiral ascent of the air bubbles. The submerged needle plays quite a vital role in influencing the rising path of the bubbles.

Fig. 3. (a-c) Multiple air bubbles rising in water following a spiral trajectory in the x-y plane. In (d-f) the yellow line shows the path of the bubbles

3.1.2. Y, Z Plane

The characteristics of flow of these bubbles were also analysed, for the same flow rate along the Y-Z axis plane. The frames in second of the obtained images was again kept to 20 frames per
image as even that in Figure 4 (a-c). Figure 4 (d-f) presents rising path of bubbles. Here again the yellowish line indicates the similar spiral rise rather than a rectilinear ascent.

Fig. 4. Spiral trajectory is followed by the multiple bubbles of air rising up in the water in different frames for the x-z axis plane. In (d-f) air bubbles are following path of the yellow line.

4. Conclusions

The rise of multiple air bubbles has been studied experimentally using tech like high-FPS digital camera that is 420 fps. Images from both the planes were analyzed. The experiments performed presented the conclusion that bubbles follow a spiral form of rise instead of going up in straight line. The submerged needle is important when it comes to determining the pathways on which rising bubbles move in because which generates some disturbance at inlet which tends the bubbles to movie in a rising spiral path. Using the needle influences path of rising air bubbles. It was also concluded that rise of the air bubbles does not depend on the flow rate.
References


