MECHANISM OF FREE SURFACE BUBBLE COLLAPSE

Sangeeth K[*], Baburaj A P[*a)] & Emil J Hopfinger[**]
[*]*Fluid Mechanics Lab, Department of Applied Mechanics, IIT Madras, Chennai, 600036, India*
[**]*LEGI*

Summary Experiments were conducted for studying the bubble burst phenomenon and jet formation. The variation of jet velocity with respect to radius is established. The stages leading to jet formation are well studied using high speed imaging. The behaviour near suspected singularity region is predicted by using Glycerol- Water mixture as fluid.

Bursting of free surface bubbles result in the formation of fast moving liquid jet. This phenomenon was studied numerically by Boulton Stone (1993) and Duchemin et. al (2002). But their jet velocity at free surface is showing considerable variation with each other. Duchemin et.al, performed simulation for a wide range of bubbles and the velocity is varying as R-1/2 for R>0.5 mm. On the other hand Boulton Stone predicts R-1 variation for the same range. These contradicting results have to be verified experimentally since no one has measured jet velocity for reasonable range of bubbles. Also the bubble cavity collapse mechanism could be considered as singular, analogous to other physical singularities in nature such as standing wave collapse (Zeff, 2000).

We study this phenomenon by analyzing the images taken in a high speed CCD camera. Capillary tubes of different sizes were used for producing bubbles of different sizes inside the liquid. The liquid was taken in a transparent acrylic tank (c/s 2x5 cm2) and filled up to the brim level for avoiding the meniscus. Air was fed into the capillary by operating a syringe pump running at constant discharge. The released bubble from the capillary would occupy at the free surface for a short time and eventually will burst. The discharge was selected in such a way to avoid crowding of bubbles at the free surface thereby eliminating the possibility of bubbles merging. High intensity LED lighting was used as back lighting.

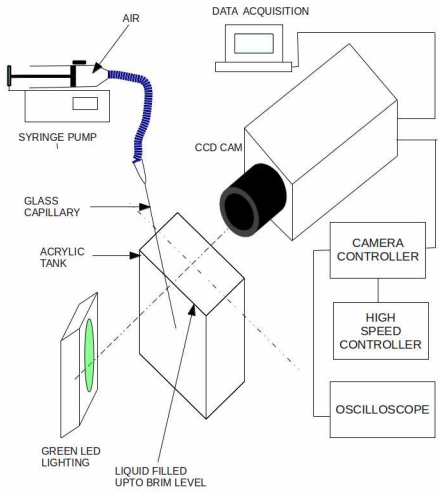


Fig 1: Experimental Set up-schematic.

Images were taken for measuring 1. undeformed bubble radius R, when the bubble is rising in the liquid, 2. quasi- static parameters of the bubble and 3. the bubble burst. The speed of CCD camera was selected conveniently upto 19,000 Hz for capturing the bubble burst. Water and Glycerol- Water mixture (63.18 % of Glycerol) were used as fluids and bubbles of the range 0.42mm < R < 2.7mm was produced.

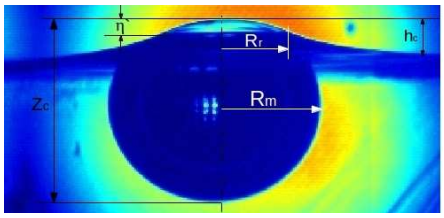


Fig 2: Representation of Quasi-static parameters

The variations of the static parameters in Fig 2 were studied with respect to undeformed bubble radius R. It is inferred that smaller bubbles (R < 0.3 capillary length) are not deformed in a significant way as like larger bubbles.

Fig 3 shows stages of bubble bursting process. Each image is having a time difference of 1/3000 sec. From the figure, the exposed rim may cause generation of high Laplace pressure in the rim thereby making a possibility of pushing the fluid in very high speed.

[a)] Corresponding author. Email: apbraj@iitm.ac.in.

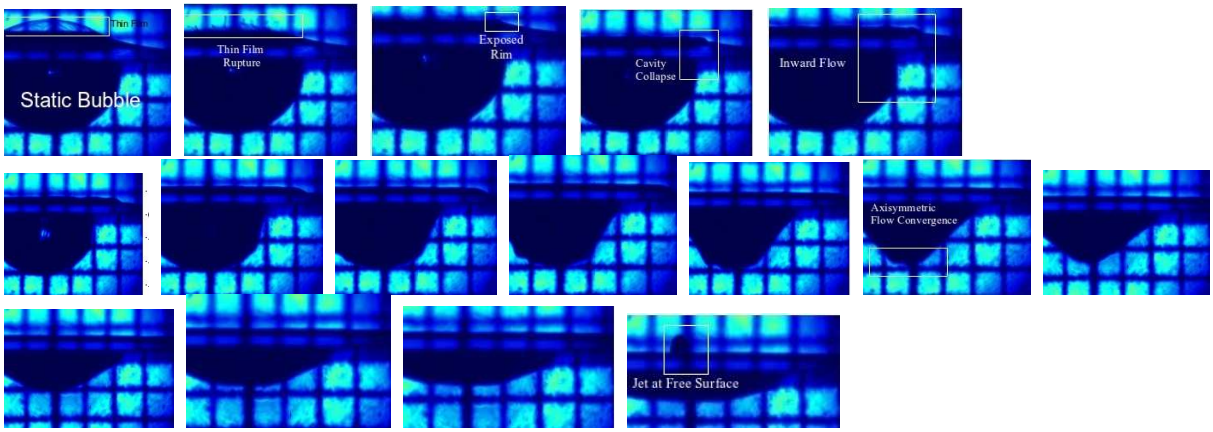
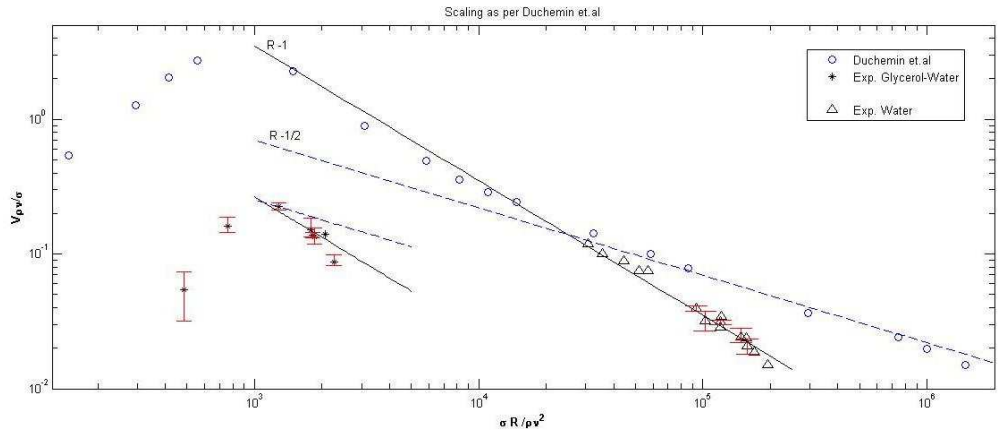


Fig 3: Different stages of bubble burst (from left to right) for bubble radius R= 2.1852 mm @3000 fps, grid size is 1 mm

The experimental velocity measurements for water follow R-1 variation which is of Boulton Stone. Possibly Duchemin was mistaken by taking spherical shape for bubbles as deformation increases with bubble radius. The Glycerol- Water data also shows R-1 variation but it is undergoing a decrease in jet velocity with decrease in bubble radius like in Duchemin, indicating a possibility of singular behavior. Duchemin's scaling doesn't comply with experimental readings using Glycerol-Water as there is an offset in data.



References

[1] J. M. Boulton-Stone, J. R. Blake.: Gas Bubble Bursting at a Free Surface. *J. Fluid Mech* **254**:437-466, 1993.
[2] .