OPEN HOUSE

Department of Chemical Engineering

2014 IIT DELHI OPEN HOUSE

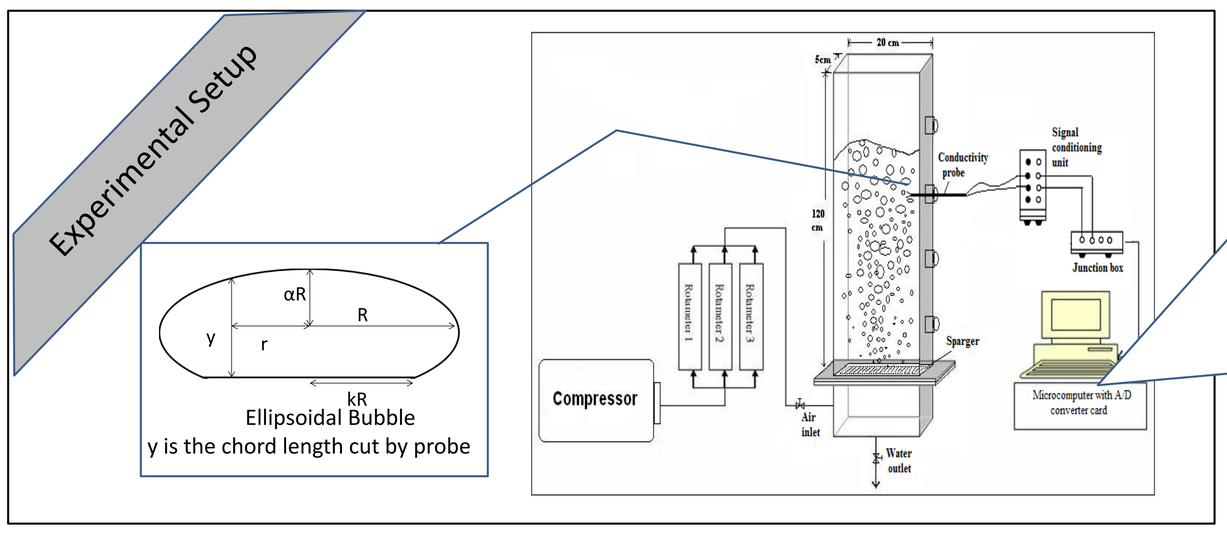
Comparison of different methods to convert chord length distribution to bubble size distribution in gas-liquid flow

Vishal Narkhede and Vivek V Buwa

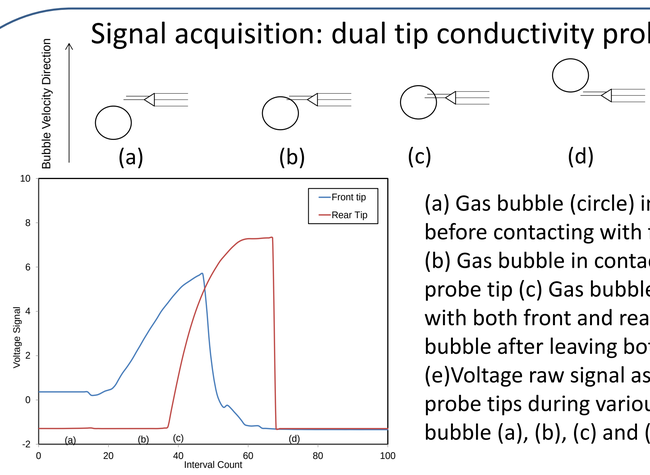
Abstract

- Gas-liquid reactors are part of every major chemical industry such as petrochemical, pharmaceutical and biochemical.
- Measurement of gas-phase property bubble size distribution has always been challenging problem.
- Cost effective non-intrusive technique using conductivity/optical probe (voidage probe) are commonly used.
- However only a chord length distribution of pierced bubbles is obtained using such voidage probe.
- Various methods for converting this chord length distribution to bubble size distribution are presented and compared in current work.

Experimental Setup

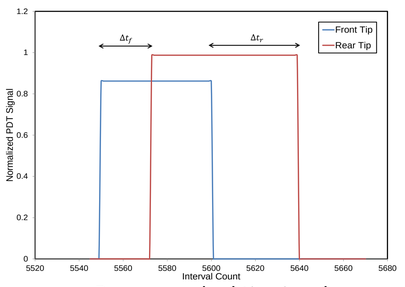


Signal acquisition: dual tip conductivity probe



(a) Gas bubble (circle) in liquid phase before contacting with front probe tip (b) Gas bubble in contact with front probe tip (c) Gas bubble in contact with both front and rear tip (d) Gas bubble after leaving both the tips (e)Voltage raw signal as acquired by probe tips during various stages of bubble (a), (b), (c) and (d)

Velocity and chord length estimation: dual tip probe



Processes dual tip signal

Velocity of j[th] bubble

$$V_j = \frac{l}{\Delta t_j} \times \frac{1}{f}$$

Chord length corresponding to j[th] bubble

$$X_j = V_j \times \Delta t_r$$

$$\Delta t_j = \frac{\Delta t_f + \Delta t_r}{2}$$

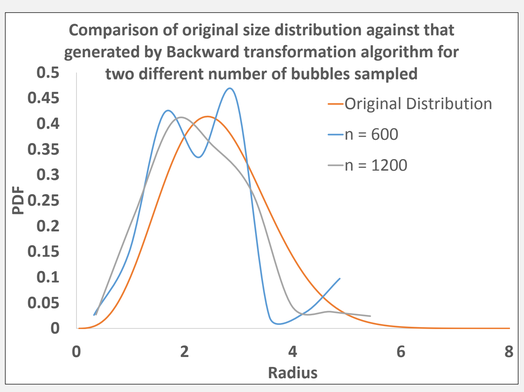
Methodology

- Experiments data of voltage signal contains lot of noise and requires lot of signal processing before obtaining chord length data as shown in figure on right side.
- Experiments were carried out by Abdul Quiyyom and Parul Tyagi (Research Scholars)
- Since actual bubble size distribution of experimental data is not known, synthetic data of chord lengths with known bubble size distribution is generated to verify accuracy of algorithms to convert CLD to BSD
- Three algorithms are analyzed here. **1. Backward Transformation Algorithm 2. Parzen's Window Method 3. Maximum Entropy Method**

Results

Backward Transformation Method [1]

- Oldest and least stable method
- Numerical method bases on Baye's theorem on conditional probability and laws of total probability



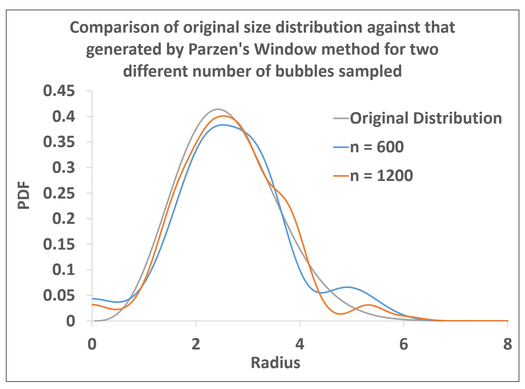
PDF estimation by Backward Transformation Method for different number of intervals (resulting instability)

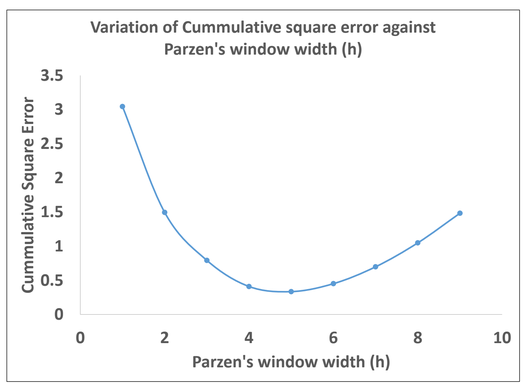
PDF for 10 intervals		
R min (cm)	R max (cm)	PR
0	0.64	0.07977
0.64	1.28	1.082541
1.28	1.92	0.25558
1.92	2.56	0.056784
2.56	3.2	0.056462
3.2	3.84	0.003078
3.84	4.48	0.008779
4.48	5.12	0.018632
5.12	5.76	0
5.76	6.4	0

PDF for more than 10 intervals		
R min (cm)	R max (cm)	PR
0	0.32	-0.252119
0.32	0.64	-0.000466
0.64	0.96	1.589625
0.96	1.28	0.874391
1.28	1.6	0.321568
1.6	1.92	0.291554
1.92	2.24	0.028531
2.24	2.56	0.07453
2.56	2.88	0.052128
2.88	3.2	0.068733
3.2	3.52	0.031945
3.52	3.84	-0.028435
3.84	4.16	0.037174
4.16	4.48	-0.021863
4.48	4.8	0.041532
4.8	5.12	0.014425
5.12	5.44	0

Parzen's Window Method [2]

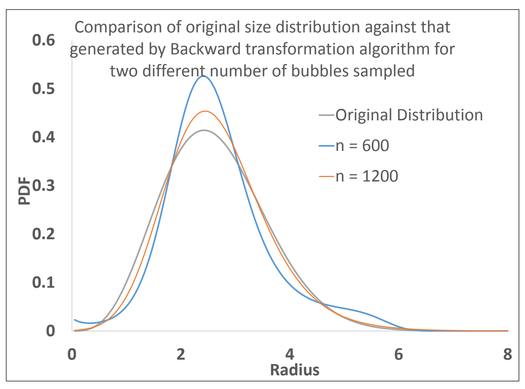
- Non-parametrical approach
- Parzen's window width is adjusting parameter which is basically width of discretization of chord length data

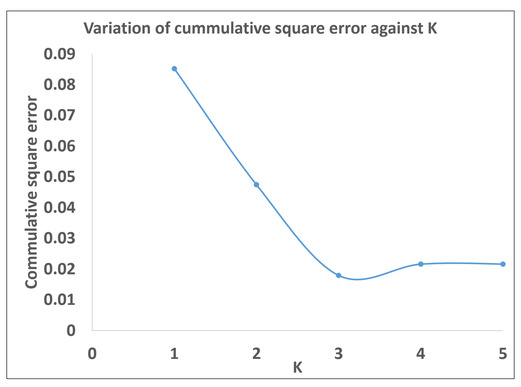


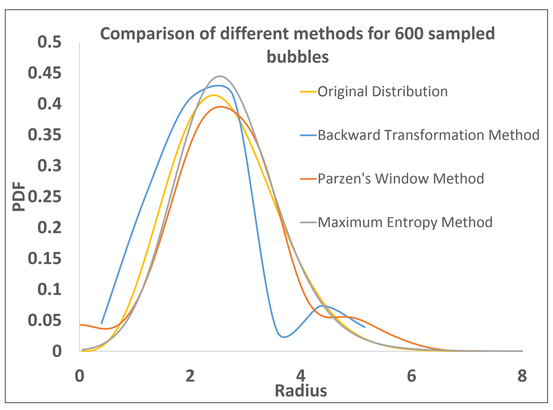


Maximum Entropy Method [3]

- Idea is to estimate a probability distribution subject to given number of raw moments (K) of chord length distribution
- Sought function is the probability distribution that maximizes the Shanon Entropy







Conclusions

- Bubble size range can be divided up to certain number of intervals to estimate BSD in case of Backward Transformation Method
- Accurate bubble size distribution is obtained at optimum value of Parzen's window width. This value decreases as number of bubble samples increases
- Maximum entropy method produce accurate results when more number of moments(K) are considered for processing. But after certain value, accuracy remains same or may also decrease.
- For all the algorithms, accuracy increases when number of bubble samples considered are increased

Reference

[1] Clark, N.N., Turton, R. Chord Length Distribution related to Bubble Size Distribution in multiphase flows, *Int. J. Multiphase Flow*, 1988, 14, 413-425

[2] Liu, W., Clark, N.N., Karamavruc, A.I., General Method for Transformation of Chord Length Data to Local Bubble Size Distribution, *AIChE Journal*, 1996, 42, 10

[3] Santana D., Rodriguez ,J., Characteristic lengths and maximum entropy estimation from probe signals in ellipsoidal bubble regime