Experimental study of the movement of single large bubbles in a closed vertical tube

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This report presents a study of single Taylor bubbles rising vertically in a stagnant liquid column, where the pulse-echo ultrasonic technique was used to measure the bubble rising velocity U_b, the bubble length L_b and the equilibrium thickness δ_{eq} of the liquid film falling around the bubble [1]. An acrylic tube of 2 m long with an inner diameter D of 24 mm, sealed at the ends and partially filled with liquid to leave an air pocket of length L_0 (Fig.1), was used. A Taylor bubble was formed by the inversion of the pipe and the rising bubble was detected by two transducers located at 70 cm and 80 cm from the top of the pipe. At least ten measurements were made for each L_0 and each liquid used (water, glycerin and mixtures of them).

The experimental results were compared with models proposed by [2] and [3] to estimate δ_{eq}, relating it with U_b. Figure 2 shows the measured and calculated values for the film thickness as a function of the Dimensionless Inverse Viscosity Number $N_f = \rho\ (gD^3)^{1/2}/\mu$ (ρ is the liquid density, μ is the dynamic viscosity and g is the gravity acceleration), characteristic of each liquid used.

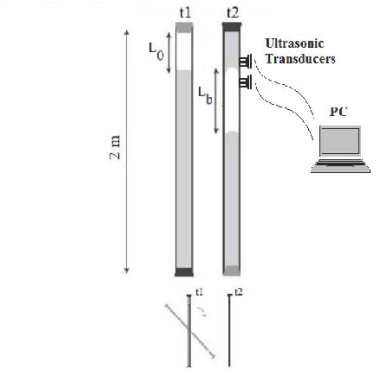

Figure 1. Schematic of the Stagnant Water Column.

In Fig. 2, it can be observed that the measured values agree very well with those calculated by the Goldsmith and Mason model [2] and by the Brown model [3], for lower viscosity liquids or higher N_f. In the first case, the disagreement observed for N_f = 15 and N_f = 224 can be attributed to a thin-film assumption ($\delta << D/2$) used in the model development. For the Brown model, the disagreement for the case of glycerin (N_f = 15), can be attributed to the constant ratio $U_b / [g(D - 2\delta)]^{1/2}$ assumed during the theoretical development. As shown in Tab.1, the ratio for glycerin is very different from those for the other liquids.

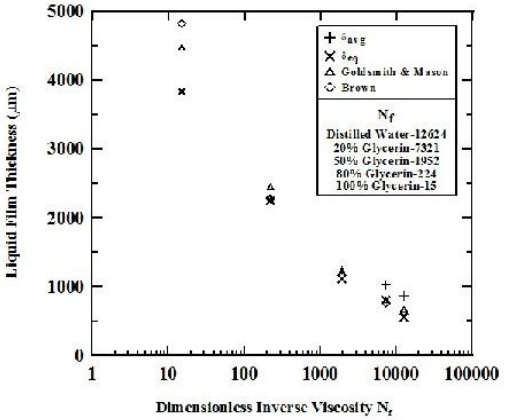

Figure 2. Measured and Calculated Film Thickness as a function of N_f.

Table 1. Air Bubble Velocities Measured for Water-Glycerin Mixtures.

	W	80W	50W	20W	G
N_f	12624	7921	1952	224	15
U_b (m/s)	0.168	0.167	0.163	0.153	0.062
$U_b / [g (D - 2\delta)]^{1/2}$	0.360	0.362	0.354	0.350	0.156

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