Ultrasonic measurements of bubble shape and liquid film thickness of a Taylor bubble rising in a stagnant water column

M. B. DE AZEVEDO [1]; J. L. H. FACCINI[1]; J. SU [2]
E-mail: bertrand@ien.gov.br

[1] *SETER/IEN* [2] *PEN/COPPE/UFRJ*

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This report presents a study of measurement of the equilibrium thickness of the falling liquid film around a Taylor bubble rising in a vertical stagnant water column, using the pulse-echo ultrasonic technique [1]. An acrylic tube of 1.8 m long with an inner diameter of 25.21 mm, sealed at the ends and partially filled with water to leave an air pocket of length L_0 = 40 cm (Fig.1), was used. A Taylor bubble was formed by the inversion of the pipe and the rising bubble was detected by a transducer located at 40 cm from the top of the pipe. Ten measurements were made for each of the four channels of the ultrasonic system, using the same settings of the system parameters, totaling 40 measured bubbles. A simplified Brown's model for the film thickness around a Taylor bubble was used to calculate a reference value of the parameter being measured [2], according to Eq. 1:

$$\delta = \left[\frac{3\nu R}{2g}(U_B - U_L)\right]^{1/3} \qquad (1)$$

where δ denotes the film thickness, ν the kinematic viscosity of the liquid, g the gravity acceleration, R is the tube radius, U_B the rising bubble velocity, and U_L is the mean liquid velocity.

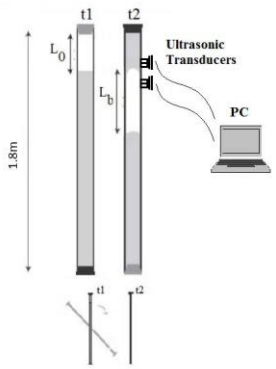

Figure 1. Schematic of the Stagnant Water Column.

Table 1 presents the values of each parameter used to estimate the film thickness for the experimental apparatus used and conditions during this work. This reference value was called δ_{ref}.

Table 1 - Parameters used to estimate δ_{ref}.

ν (m^2/s)	R (m)	g (m/s^2)	U_B (m/s)	U_L (m/s)	δ_{ref} (μm)
$8.9x10^{-7}$	0.0126	9.81	0.174	0	669

U_B estimated by Nicklin Correlation [3]

Table 2 presents the mean value of the equilibrium film thickness δ for all of the 40 bubbles, the standard deviation σ and its relative error e_{rel} to the reference value. The results presented reveal that the values of the experimentally measured film thickness are in good agreement with the expected reference value and also that the relative error between the measured value and the reference one is in the order of 10%.

Table 2 - Mean equilibrium film thickness for the 40 measured bubbles and its relative error for the reference value.

δ (μm)	728.6
σ (μm)	30.0
e_{rel}	0.0890

$e_{rel} = |\delta - \delta_{ref}| / \delta_{ref}$

The results presented in Tab. 2 reveal that the pulse-echo ultrasonic technique can be applied in the direct measurement of the equilibrium film thickness around a Taylor bubble.

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