Experimental Study of the Falling Film of Liquid Around a Taylor Bubble

M. B., Azevedo[1], D., Santos[3], J. L. H., Faccini[1], J., Su[2]
e-mail: bertrand@ien.gov.br, faccini@ien.gov.br

[1] SETER, IEN
[2] PEN/COPPE, [3]Poli/UFRJ

Keywords: Taylor bubble, falling liquid film, equilibrium film thickness, film development length, ultrasonic technique, stagnant liquid.

The present work reports an experimental study of the falling liquid film around single Taylor bubbles rising in vertical tubes filled with stagnant liquids by using a pulse-echo ultrasonic technique, [1]. The experiments were carried out in acrylic tubes 2.0 m long, with inner diameters D of 0.019, 0.024 and 0.034 m, with five water-glycerin mixtures, corresponding to inverse viscosity number ranging from 15 to 22422. The rising bubble and the falling liquid film were measured by using ultrasonic transducers located at the one side of the tube. The velocity and profile of the Taylor bubble, and the development length and equilibrium thickness of the falling liquid film around the bubble were obtained by the ultrasonic signals processing. Based on the experimental results of the present study, several correlations available to estimate the equilibrium thicknesses of liquid films falling around Taylor bubbles were evaluated, [2], [3], [4], and new correlations were proposed to estimate the dimensionless equilibrium film thickness and the film development length respectively. The experimental data were obtained from vertical columns partially filled with stagnant liquid. A Taylor bubble with length L_b was formed by the inversion ($t_1 - t_2$) of the pipe partially filled with liquid to leave an air pocket of length L_0, as illustrated in Fig.1.

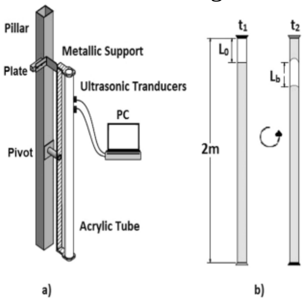

Figure 1. Schematic of the vertical column: (a)apparatus; (b) bubble formation.

Based on the experimental results obtained in the present work, we proposed new empirical correlations to estimate the dimensionless equilibrium film thickness $\delta`_{eq}$ (Fig.2) and the dimensionless film development lenght Z/D (Fig.3) for N_f ranging from 15 to 12900:

$$\delta`_{eq} = -4.19 \times 10^{-2} \ln N_f + 4.25 \times 10^{-1} \quad (1)$$

$$Z/D = 1.51 + 1.70 \times 10^{-3} N_f - 2.45 \times 10^{-8} N_f^2 \quad (2)$$

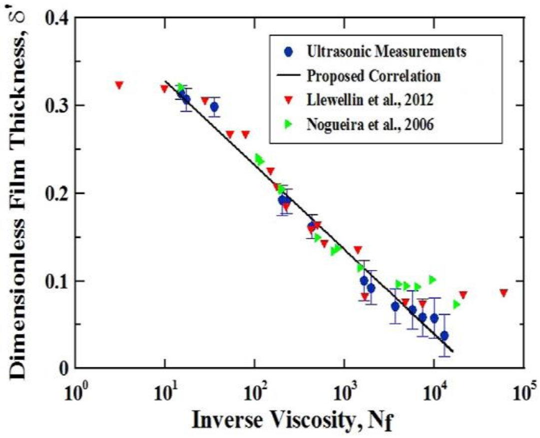

Figure 2. $\delta`_{eq}$ as a function of N_f.

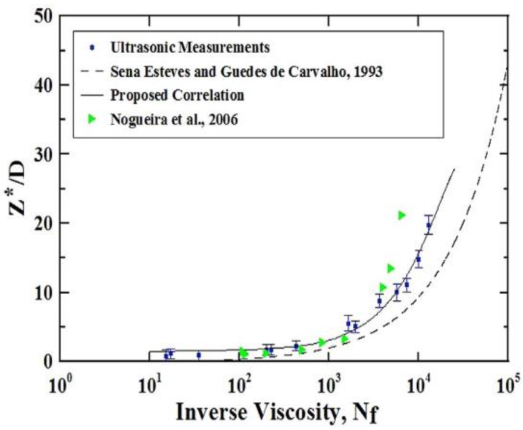

Figure 3. Z/ D as a function of N_f .

References

[1] AZEVEDO, M. B. et. al. Experimental study of the falling film of liquid around a Taylor bubble. **International Journal of Multiphase Flow**, Houston, USA, v. 88, p. 133-141, jan. 2017.
[2] LLEWELLIN, E. W., et al. The thickness of the falling film of liquid around a Taylor bubble**. Proceedings of the Royal Society A**, London, v. 468, n. 2140, p. 1041-1064, abr. 2012.
[3] NOGUEIRA, S. et al. Flow in the nose region and annular film around a Taylor bubble rising through vertical columns of stagnant and flowing Newtonian liquids**. Chemical Engineering Science**, Valencia, Spain, v. 61, n. 2, p. 845-857, jan. 2006.
[4] SENA, M. T. E. ; GUEDES, J. R. F. C. Liquid-side mass transfer coefficient for gas slugs rising in liquids. **Chemical Engineering Science**, [s. l.], v. 48, n. 20, p. 3497-3506, out.1993.