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The dynamics of a gas bubble moving through a tube or channel is a problem that has received considerable attention due to its close connection with many interesting mechanical and biological processes such as multiphase flow in porous materials and the motion of gas bubbles in the bloodstream. However, to our knowledge there is very little published data on the hydrodynamic behavior of such bubbles in inclined rectangular channels.

We present the results of experimental investigation on the dynamics of air bubbles rising in stagnant or co-flowing liquid inside an inclined rectangular channel. Variable channel geometry (with adjustable height H, perimeter $P = 2(H + W)$, inclination α, and orientation – flat $H < W$ or tall $H > W$) enabled us to evaluate the influence of different operation parameters on the bubble shape and velocity. Measurements of the rise velocity of large Taylor bubbles (U_{TB}) were carried out by using a high-speed video camera system and an image processing technique.

The results obtained in all channel configurations suggest that sufficiently large bubbles reach a final rise velocity U_{TB}, which is no more sensitive to further increasing in the bubble size. In vertical channels, this final bubble velocity U^{v}_{TB} is controlled by the channel perimeter P and a universal velocity scaling based on the Froude number $Fr_v = U_{\mathrm{TB}}/(g \cdot P)^{1/2} \cong 0.2$[1] was confirmed. In horizontal channels, the final translating velocity U^{h}_{TB} is controlled by the channel height H and the scaling based on the Froude number $Fr_h = U_{\mathrm{TB}}/(g \cdot H)^{1/2} \cong 0.5$[2] is recommended for large channels. U^{h}_{TB} values obtained in our experiments by velocity data extrapolation indicate that the surface tension plays an important role in flat channels. Fr_h was found to be decreasing with increasing surface tension parameter $\sum = 4\sigma/\rho g H^2$.

In inclined channels, different character of $U_{\mathrm{TB}}(\alpha)$ dependence was observed for flat and tall channel orientations. In flat channels there was a monotonous increase of U_{TB} with α, whereas in the tall channels there was a velocity maximum observed at moderate α. Therefore, the bubble velocity scaling based on a weighted superposition of

U^h_{TB} and U^v_{TB} and proposed for large inclined tubes[3], has to be modified. Our experimental data suggests a new relationship in the form $U_{TB} = U^v_{TB} \sin^m \alpha + U^h_{TB} \cos^n \alpha$, where the power parameters m and n are both dependent on the channel geometry. The first parameter m distinct between flat ($m = 1/2$ for $H < 10$ mm) and tall (m=1 for $H > 20$ mm) channels, whereas the second parameter n is found to be linearly dependent on U^h_{TB}/U^v_{TB} ratio and ranging between 1 and 2 in our experiments.

The electrodiffusion method was then used to measure wall shear stress induced by rising bubbles. Measurements were done with sensors positioned on both sides of the channel to reflect the asymmetric shape of bubbles rising in inclined channels. The typical wall shear stress profile induced by a rising bubble is characterized by a positive peak at the position of the bubble nose, negative peak in the liquid film under the bubble, and fluctuating values for the unsteady flow inside the bubble wake. Depending on the location of sensors (roof or bottom wall), some general trends of wall shear stress dependence on the bubble size, channel inclination, and liquid flow rate were observed.

References

1. Clanet, C.; Heraud, P.; Searby, G. On the motion of bubbles in vertical tubes of arbitrary cross sections: some complements to the Dumitrescu-Taylor problem. *J. Fluid Mech.* **2004**, *519*, 359–376.
2. Benjamin, T. B. Gravity Currents and Related Phenomena. *J. Fluid Mech.* **1968**, *31*, 209.
3. Bendiksen, K. H. An Experimental Investigation of the Motion of Long Bubbles in Inclined Tubes.*Int. J. Multiphase Flow* **1984**, *10* (4), 467–483.