Effect of BMIM-BF4 Concentration in Water on the Lift Force Coefficient of Rising Single Bubbles.

Djamel Eddine Aissaoui[1], Nicolò Varallo[1], Lantian Wang[2], Hendrik Hessenkemper[2], Giorgio Besagni[1,2]

[1]Politecnico di Milano, Department of Energy, Milan, Italy

[2]Helmholtz-Zentrum Dresden-Rossendorf, Institute of Fluid Dynamics, Dresden, Germany

Abstract

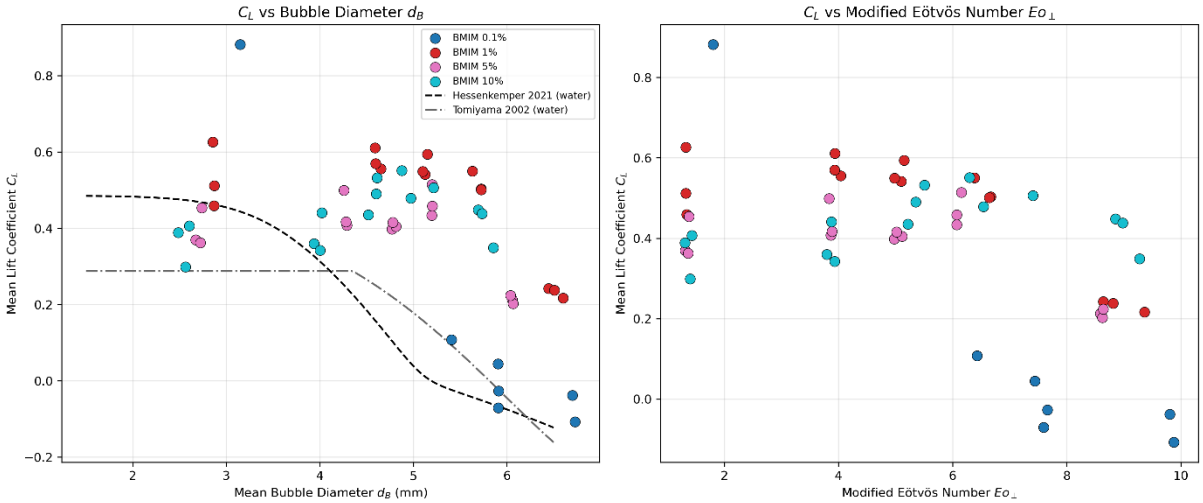
Ionic liquids (ILs) are increasingly explored as solvents for CO2 capture, because of their essentially non-volatile character, thermal stability, and the ability to tailor their properties through cation-anion selection. Bubble column reactors are a natural fit for such IL-based absorption processes, offering a simple mechanical design combined with high interfacial area for mass transfer between the gas and liquid phases.

The shear-induced lift force governs the lateral migration of bubbles in gas–liquid shear flows and must be accounted for in CFD simulations of bubble columns. Established lift-coefficient (C_L) correlations, such as those of Tomiyama et al. (2002) and Hessenkemper et al. (2021), do not hold for ionic-liquid-water solutions, since the presence of the ionic liquid at the bubble interface is expected to strongly affect surface properties and hence bubble fluid dynamics. A reliable lift coefficient correlation for these systems is therefore needed for accurate CFD simulations, which in turn are essential for tasks such as the scale-up of bubble column reactors.

In this work we experimentally determine the lift coefficient of single air bubbles rising in aqueous solutions of the ionic liquid 1-butyl-3-methylimidazolium tetrafluoroborate (BMIM-BF4) at concentrations of 0.1, 1, 5 and 10 wt%. Measurements were performed with the shear-flow method of Ziegenhein et al. (2018), for bubble diameters between 2 and 6.5 mm.

The results show a clear and systematic deviation from the clean-water reference correlation of Hessenkemper et al. (2021). While clean water shows the expected decrease of C_L with increasing bubble size and Eo⊥, crossing from positive to negative values above roughly d_B = 5.2 mm, bubbles in BMIM-BF4 solutions retain positive lift coefficients (C_L ≈ 0.2-0.6) across the entire investigated size range, with the sign reversal delayed or suppressed. This also contrasts with the parabolic concentration-dependence reported by Hessenkemper et al. (2021) for organic surfactants (1-Pentanol, Triton X-100), where C_L first rises then falls back toward zero with increasing contamination: across the full 0.1-10 wt% BMIM-BF4 range, C_L remains positive and does not show this decline toward zero.

These findings show that the lift coefficient in ionic-liquid solutions differs from reported values in the literature for other contaminants, with direct implications for the design and simulation of IL-based gas-liquid contactors, e.g. for CO2 capture. The results presented in this study are a first step toward the definition of a lift-coefficient correlation for ionic-liquid systems.



Measured lift coefficient C_L of single air bubbles in aqueous BMIM-BF4 solutions (0.1-10 wt%) vs. bubble diameter d_B (left) and modified Eötvös number Eo⊥ (right), compared to the clean-water reference correlation of Hessenkemper et al. (2021, dashed).