A Predictive Hydrodynamic Criterion for Pickering Foam Formation by Hybrid Eulerian Multiphase Population Balance Modeling

Kang Wang, Vivekananda Sinha, Marc Pera-Titus

Cardiff Catalysis Institute, School of Chemistry, Cardiff University, Main Building, Park Place, Cardiff CF10 3AT, UK

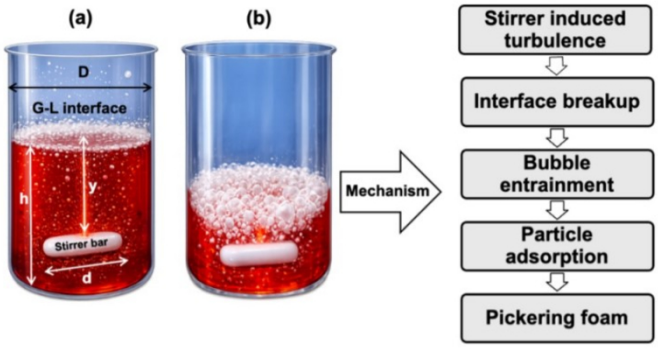
WangK40@cardiff.ac.uk

Particle-stabilized (Pickering) foams offer a versatile platform for intensifying gas-liquid-solid reactions by combining high interfacial area with the ability to anchor catalytic particles at gas-liquid interfaces.[1 2 3] Despite their promise, the rational design and scale-up of Pickering foam reactors remain limited by the absence of predictive criteria linking hydrodynamics to foam inception.

Here, a predictive hydrodynamic criterion for the onset of Pickering foam formation in stirred reactors is established. By integrating systematic foaming experiments with a hybrid Eulerian multiphase computational fluid dynamics–population balance modelling framework, a critical instability threshold is identified. Foam formation is shown to emerge when the normalised stirrer–interface position exceeds 0.7 and the stirrer-to-reactor diameter ratio surpasses 0.5. This transition corresponds to a near-interface Weber nd Froude-number regime in which turbulent inertial stresses overcome interfacial tension and gravity, leading to bubble entrainment that is subsequently stabilised by particles. This coupled model framework quantitatively captures bubble size distributions and accurately delineates foam and no-foam regimes across a wide range of reactor configurations, enabling the construction of a generalised dimensionless foamability map.

These findings provide a unified and predictive framework for understanding and controlling Pickering foam formation, offering a robust foundation for the scale-up and design of intensified multiphase catalytic reactors and other technologies exploiting structured gas-liquid interfaces.

Keywords:
Pickering foam, interfacial catalysis, population balance model, gas entrapment, bubble



Schematic and step by step mechanism of the foam formation in tube reactors depending upon stirrer-interface proximity. (a) No foam when the stirrer is away from the G-L interface (b) vigourous foaming when the stirrer is close to the interface. D: tube diameter; d: stirrer bar length; h

References:

[1] Kang Wang, Marc Pera-Titus. Microstructured gas-liquid-(solid) interfaces: A platform for sustainable synthesis of commodity chemicals[J]. Science Advances, 2024.

[2] Kang Wang, Josh Davies-Jones, Arthur Graf, Marina Carravetta, Philip R Davies, Marc Pera-Titus. Amphiphilic Janus particles for aerobic alcohol oxidation in oil foams [J]. ACS Catalysis, 2024.

[3] Shi Zhang, Dmytro Dedovets, Andong Feng, Kang Wang, Marc Pera-Titus. Pickering interfacial catalysis for aerobic alcohol oxidation in oil foams [J]. Journal of the American Chemical Society. 2022.