Dynamical behavior of an aqueous foam in a liquid-filled Hele-Shaw cell

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ABSTRACT

Foam, that is, a dispersion of gas bubbles in a liquid, is found in many of our products and processes, e.g., medical applications to cleaning agents to enhanced oil production. In contrast to a single-phase gas, foam exhibits a viscosity higher than the gas phase viscosity. In the research documented here, the miscible displacement of an aqueous foam with a dispersity of 30% and an average bubble radius of $68 \pm 2\ \mu m$ in a liquid-saturated Hele-Shaw cell is examined. The main goal of this experimental study is to investigate the influence of the dynamical surfactant dilution of foam on the interfacial flows in which the viscous force is favourable. Foam bubbles are categorized based on gap thickness of the Hele-Shaw cell (b) into two groups: (i) small bubbles with a dimensionless average radius of $0.45 \leq \bar{R}/b \leq 0.54$, (ii) and large bubbles with $0.81 \leq \bar{R}/b \leq 7.72$. Movement of foam with various qualities (gas fractions) is monitored when the Hele-Shaw cell is initially filled with (i) DI-water and (ii) SOS at 17 times critical micelle concentration (CMC) that has the same surfactant concentration as the injected foam. Outcomes show that the displacement process remains stable in the surfactant-saturated Hele-Shaw cell whereas fingers of foam evolve in the water case. The growth of the ramifications, however, is retarded when the foam quality reduces. Since the total flow rate of the injected foam changes with the foam quality, another experiment is performed to decouple the impact of the flow rate from the surfactant dilution on the pattern formation. The injection of foam with a constant quality of 80% into (i) DI-water, (ii) 0.5CMC, and (iii) 17CMC elucidates that the uniform distribution of foam into 17CMC replaces with small interfacial perturbations when the Hele-Shaw cell is filled with 0.5CMC. The phase diagram of the pattern formation illustrating the effect of foam quality and surfactant concentration of defending fluid confirms that the highest interfacial deviation occurs when the foam with high quality is injected into a DI water-filled Hele-Shaw cell. The results suggest that water diffusion into the foam enhances the capillary force, which in turn promotes the ‘pinning’ of large foam bubbles separated from the solid surface by fragile thin films. The break-up of the lubricated thin films leads to a failure in the continuous movement of the large bubbles, thereby leading to a disturbance of the spatial distribution of foam flow and side branching patterns. This interfacial deformation can be aggravated through a local jamming structure when the number of small bubbles in a unite volume at the interface is higher than 50%.

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