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Dispersion of a passive scalar around a confined bubble

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The study of mass-transfer in confined geometries is extremely important in many engineering and biological systems. In the context of geological carbon sequestration, carbon dioxide is injected into subsurface reservoirs leading to the formation of elongated bubbles that can either be trapped, move, or interact with the solid matrix. The presence of carbon dioxide has the effect of increasing the acidity of the in-situ brine, boosting a series of chain reactions that enhance rock dissolution. This may threaten the long-term integrity of the storage process due to the formation of leakage pathways for carbon dioxide.

Although the hydrodynamics of elongated bubble has been object of several studies, the case where a solute is transported in the surrounding liquid and surface mass-transfer mechanisms act on the solid wall or the bubble-fluid interface is much less understood. To fill this gap, we investigate the transport problem around a confined Taylor bubble to access the competition between advection, diffusion, and surface mass-transfer in the different regions of the bubble. To this aim, we derive a one dimensional Advection-Diffusion-Mass-Transfer equation where the transport mechanisms are described through an effective velocity, an effective diffusion coefficient, and an effective Sherwood number. Our model generalises the Aris-Taylor dispersion to the case of a Taylor bubble and clarifies the impact of surface mass-transfer in the advection and diffusion dominated regimes for both the front and rear menisci.

Despite the fact that the motivation of our work is oriented to microfluidics applications that involves solute transport and mass-transfer, its ramifications are relevant also in scenarios where the presence of a solute affects the surface tension (i.e., Maragoni effect) or even drives the flow (i.e., diffusioosmosis).

Participation

In-Person

References

Picchi, D., & Poesio, P. (2022). Dispersion of a passive scalar around a Taylor bubble. Journal of Fluid Mechanics, 951, A22. doi:10.1017/jfm.2022.829

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