Bubbles in Yield Stress Fluids: Link between the Rheology and Stability of Bubbles

Masoud Daneshi[1], Ian Frigaard[1,2]
[1]Department of Mathematics, University of British Columbia, Vancouver, Canada
[2]Department of Mechanical Engineering, University of British Columbia, Vancouver, Canada

ABSTRACT

In this work, we study the mechanics of bubbles in a yield stress fluid. This scenario can be found in a wide range of industrial and natural settings including natural and man-made ponds, flooded soils, terrestrial sediments, and other industrial fluid/paste storage scenarios. The original motivation of this work stems from gas emissions from oil sands tailings which is a by-product of the oil sands production process. Microbial degradation of naphtha hydrocarbons and naphthenic acids in the FFT/MFT layers of oil sands tailings ponds leads to the generation of methane and carbon dioxide. The FFT and MFT layers are colloidal suspensions, which behave like viscoplastic fluids with time-dependent rheology. The key feature of a viscoplastic fluid is its yield stress: the material flows only if the imposed stress exceeds the yield stress. This raises questions regarding the stability of bubbles that are trapped in a yield stress fluid, which we try to answer in this research through a series of targeted experiments with model yield stress fluids, Carbopol and Laponite. A vacuum chamber system was used to control the concentration and size of bubbles trapped in the fluid.

A series of experiments have been performed to investigate the growth and stability of bubble clouds in gels with different concentrations. Our objective is to find a link between the rheology of the gel and the maximum gas concentration that can be trapped in the gel and the shape and size of the bubbles at the onset of motion. Our results show increasing the gel concentration, i.e. the yield stress of the gel, improves the capacity for gas retention. In addition, our study confirms that bubble clouds become unstable at a smaller bubble size in comparison with that of a single bubble. This is likely related to the interaction of the stress fields developing around the bubbles or their coalescence. To further investigate this point, we extend our study by looking at more fundamental scenarios, i.e. two or three bubbles at different orientations and separation distances. We examine this problem using both an experimental and a numerical approach to demonstrate how the stress fields around neighbouring bubbles interfere with each other and how this affects their onset of motion in a yield stress fluid.

ACKNOWLEDGEMENT

This research was made possible by funding from NSERC and COSIA/IOSI (project numbers CRDPJ 537806-18 and IOSI Project #2018-10).