Detergent-Driven Dripping Droplets

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Using detergents and soaps in cleaning products to remove oily stains from clothes, etc, is a familiar everyday occurrence. Chemically, these substances are usually a mixture of surfactants that lower the surface tension between the trapped oil and the (washing) water phase, so that the two mix more easily and the oil phase can be swept away. Gradients in surfactant concentration on an interface cause Marangoni forces whose effects can be observed in table-top experiments, such as in the spontaneous propulsion of small floating rafts using only some kitchen detergent as 'fuel', see[1].

Understanding how surfactants affect water-oil systems is important for a whole range of technologies. The motivation for this work, but far from the sole application, comes from the process of 'enhanced oil recovery' in which a complex surfactant-laden fluid is pumped into a porous reservoir in order to release the oil which remains trapped and immobile to simple water-flooding techniques. In many cases this can be almost half of the oil originally in the reservoir.

Often, rather than studying the flow of a complex fluid through a porous network, more insight can be gained from studying the dynamics of liquids in simplified geometries. This often involves putting drops of oil into water-surfactant mixtures. This Industrial Maths Mini-Project will consider a recent discovery on such a system, made by the Bain Group in Durham[2], which thus far has eluded a theoretical description. Counter-intuitively, it is seen that when an oil drop is placed in a channel of water-surfactant mixture, the water phase spontaneously and repeatedly drips right through the oil drop, see Figure 1.

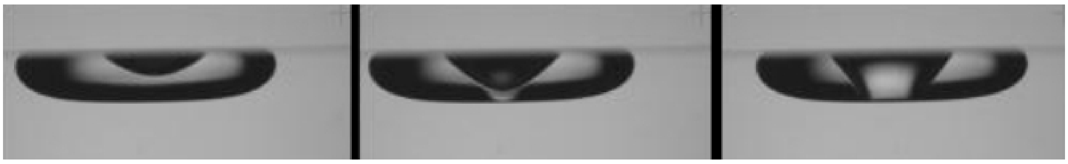

Figure 1: A 'dripping drop' showing water phase building up on top of an oil drop until it has sufficient weight to puncture it. Courtesy of M. Pope and C. Bain (Durham).

The Mini-Project proposed will require the development of a computationally tractable mathematical model for this process which can then be compared, and improved upon if necessary, to the available experimental data.

A number of potential PhD topics follow naturally on from this Project. Two fields where progress is desperately needed are in the modelling complex fluids in confined geometries and in approaches to 'up-scaling' the behaviour of such fluids through complex porous networks. Progress in either of these directions would be of significant interest to both academia and industry, with Schlumberger certainly keen to collaborate on any such project.

Schlumberger is an oilfields services company employing 123,000 people across 85 countries, see[3]. **Dr Andrew Clarke** is a Principal Scientist in Advanced Recovery at their laboratories in Cambridge whose research focuses on understanding the flow of complex fluids through porous structures.

Dr James Sprittles is a IAS Global Research Fellow in Mathematics for the next 5 years whose details are on his webpage: `http://homepages.warwick.ac.uk/staff/J.E.Sprittles/`.

References

[1] The Marangoni Effect: How to make a soap propelled boat! `http://youtu.be/rq55eXGVvis`.

[2] Professor Colin Bain's Research Group. `http://www.colinbain.net/`.

[3] Schlumberger. `http://www.slb.com`.