Center for Environmental & Applied Fluid Mechanics

"Achieving Drag Reduction using Superhydrophobic Surfaces, even with Real-World Contaminants"

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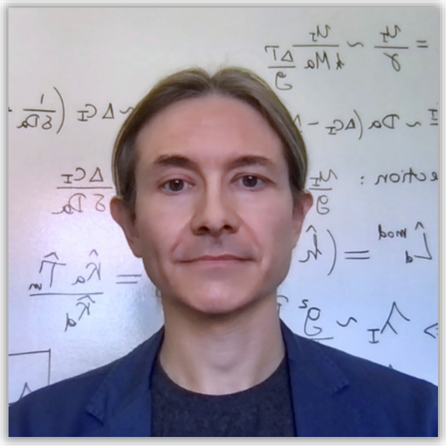

Superhydrophobic surfaces (SHS) have the potential to yield enormous technological benefits in fields ranging from microfluidics to maritime transportation, due to their ability to reduce drag. By combining hydrophobicity and microscopic surface patterning, these substrates retain a layer of air when submerged in water, thereby reducing friction. However, experiments have provided inconsistent results, with many SHS yielding little or no drag reduction. It has been hypothesized that naturally-occurring surfactants could be responsible, by creating adverse Marangoni stresses. However, testing this hypothesis has proven challenging. Experiments with purified water already show large interfacial stresses and, paradoxically, adding surfactants yields barely measurable drag increases, thus casting doubt on this hypothesis. Mathematical modeling is also arduous, as the flow/surfactant problem comprises six nonlinearly-coupled partial differential equations, for which exact solutions are unlikely to be found.

To test the surfactant hypothesis, we introduce simulations inclusive of surfactant transport, which enable controlling surfactant concentrations with higher precision than can be achieved experimentally. The simulations reveal that Marangoni stresses can immobilize the air–water interface even for concentrations below typical environmental values. We confirm these findings experimentally, and devise a demonstration whereby the interplay of geometry and trace surfactant enables a drop of soap to solve a liquid-filled maze. By performing a scaling analysis, we derive a manageable mathematical model of these flows, which is in agreement with our experiments and simulations. Although the general problem comprises ten dimensionless groups, we discover that surfactant effects on SHS can be predicted by a single parameter, expressing whether the interface is longer than a key "mobilization length" associated with the surfactant properties. These findings advance the fundamental understanding of interfacial flows, and provide strategies to design SHS capable of drag reduction in realistic conditions.

Fall 2022 CEAFM Seminar Series

November 4, 2022 ⌘ 3:00 PM ⌘ Gilman Hall 50

https://wse.zoom.us/j/93762992307

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