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Predicting longevity of submerged superhydrophobic surfaces with parallel grooves

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A mathematical framework is developed to predict the longevity of a submerged superhydrophobic surface made up of parallel grooves. Time-dependent integro-differential equations predicting the instantaneous behavior of the air–water interface are derived by applying the balance of forces across the air–water interface, while accounting for the dissolution of the air in water over time. The calculations start by producing a differential equation for the initial steady-state shape and equilibrium position of the air–water interface at $t = 0$. Analytical and/or numerical solutions are then developed to solve the time-dependent equations and to compute the volume of the trapped air in the grooves over time until a Wenzel state is reached as the interface touches the groove's bottom. For demonstration, a superhydrophobic surface made of parallel grooves is considered, and the influence of the groove's dimensions on the longevity of the surface under different hydrostatic pressures is studied. It was found that for grooves with higher width-to-depth ratios, the critical pressure (pressure at which departure from the Cassie state starts) is higher due to stronger resistance to deflection of the air–water interface from the air trapped in such grooves. However, grooves with higher width-to-depth ratios reach the Wenzel state faster because of their greater air–water interface areas. © *2013 AIP Publishing LLC*. [http://dx.doi.org/10.1063/1.4811830]

I. INTRODUCTION

Superhydrophobicity is a phenomenon that results from a combination of hydrophobicity and micro/nano roughness.[1] A superhydrophobic surface possesses strong non-wetting characteristics because of its ability to trap some air pockets in its pores. Superhydrophobicity has first been observed in nature. Lotus leaves, feet of water striders, sharkskin, and wings of many insects are examples of plants and animals possessing superhydrophobic surfaces.

The drag force exerted by a stream of water on a superhydrophobic surface is less than that on a similar surface which is not superhydrophobic. This is because the air trapped inside the pores of a superhydrophobic surface reduces the contact between the water and the solid surface. There are numerous studies dedicated to quantifying the reduction in the skin-friction drag on submerged objects or micro channels with superhydrophobic surfaces (see, e.g., Refs. 2–6).

Superhydrophobic surfaces are usually made by imprinting micro/nano scale structures on a hydrophobic substrate, or by applying surface treatments to substrates with desired roughness. An alternative approach to produce a superhydrophobic surface is by depositing hydrophobic fibers or particles on a substrate (see, e.g., Refs. 7–10).

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