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Instantaneous slip length in superhydrophobic microchannels having grooves with curved or dissimilar walls

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Superhydrophobic (SHP) surfaces can be used to reduce the skin-friction drag in a microchannel. This is due to the peculiar ability of these surfaces to entrap air in their pores and thereby reduce the contact area between water and the solid surface. The favorable drag-reduction effect, however, can quickly deteriorate if the surface geometry is not designed properly. The deterioration can be sudden, caused by exposure to excessive pressures, or gradual, due to the dissolution of the entrapped air into the ambient water. The formulations presented here provide a means for studying the time-dependent drag-reduction in a microchannel enhanced with transverse or longitudinal SHP grooves of varying wall profiles or wettabilities. Moreover, different mathematical approaches are developed to distinguish the performance of a sharp-edged groove from that of a groove with round entrance. The work starts by deriving an equation for the balance of forces on the air–water interface (AWI) inside a groove and solving this differential equation, along with Henry's law, for the rate of dissolution of the entrapped air into water over time. It was shown that the performance of a SHP groove depends mostly on the interplay between the effects of the apparent contact angle of the AWI and the initial volume of the groove. The instantaneous slip length is then calculated by solving the Navier–Stokes equations for flow in microchannels with SHP grooves. Our results are compared with the studies in the literature whenever available, and good agreement has been observed. © *2015 AIP Publishing LLC.* [http://dx.doi.org/10.1063/1.4931588]

I. INTRODUCTION

Concerned with the excessive pressures required to pump aqueous solutions through a microchannel, superhydrophobic (SHP) surfaces have been suggested as a wall treatment to potentially reduce the skin-friction drag in the channels.[1,2] A SHP surface is generally comprised of a micro- or nanoscale texture made of (or coated with) a hydrophobic material. A peculiar property of a SHP surface is that it can entrap air in its pores and thereby reduce the contact area between the solid surface and water. The reduced solid–water contact area may then result in a reduction in the friction between the wall and the flow. Studies reporting on the use of SHP micro-posts and micro-grooves in channels include, but are not limited to, the experimental and theoretical work of Refs. 3–9.

Depending on the geometry and operating conditions, the Cassie state (fully dry), the Wenzel state (fully wetted), or a series of transition states in between the Cassie and Wenzel states can exist for a SHP surface in a microchannel. Departure from the Cassie state under elevated pressures is often characterized in terms of a critical pressure, as will be discussed later in this paper. In fact, there are two paths by which a submerged SHP surface may transition from the Cassie state to

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