Superhydrophobic surfaces for friction reduction applications

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Introduction: Inspired by the unique water-repellent properties of the lotus leaf, superhydrophobic surfaces can be employed by applying a hydrophobic coating on a rough or textured surface. Maintaining a dewetted (Cassie state) condition as illustrated in Figure 1, the wetting of the groove is averted, leaving air pockets filling up the gap beneath the liquid interface.

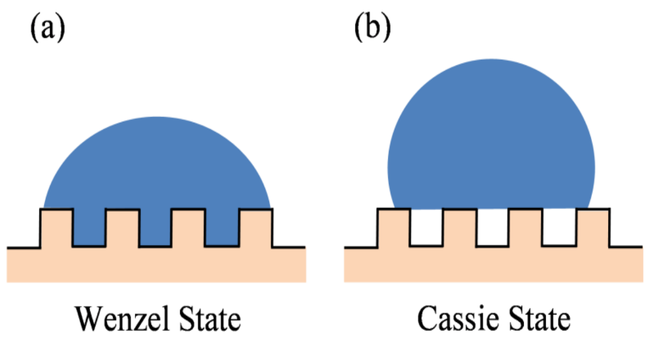

Figure 1. Wetting behavior on a microtextured surface

Scope: The present work investigates the role of suspended liquid-gas interfaces for applications involving the reduction in flow resistance using the COMSOL multiphysics software. A pressure-driven viscous flow of a liquid through microtubes containing superhydrophobic surfaces patterned with alternating micro-grooves and ribs has been considered. Employing a 3D simulation, a fully-developed laminar flow with a uniform bulk velocity has been simulated.

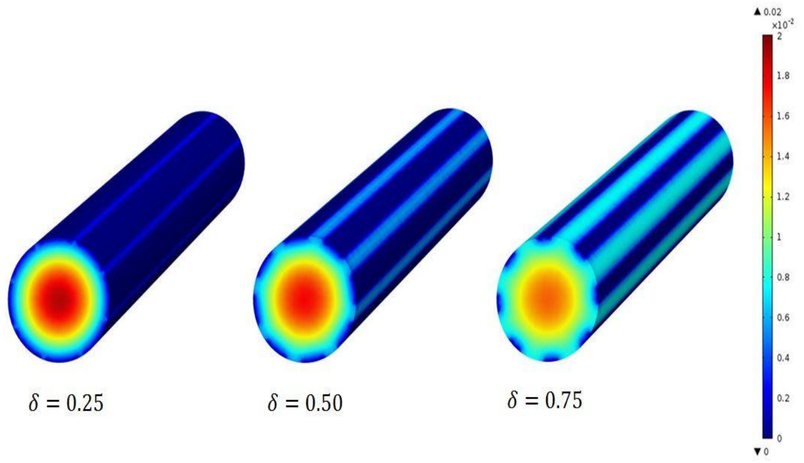

Figure 2. Streamwise velocity field for flow in a tube with different values of shear-free fraction

Results: As can be observed in Figure 3(a), the results yielded by both analytical and numerical methods are in good agreement. An increase in the value of the shear-free fraction (relative wall surface area occupied by the grooves) gives rise to a corresponding increase in the normalized effective slip length. A finite positive effective slip length is also equivalent to a decreasing friction factor-Reynolds number product, and thus a reduction in flow resistance through the tube, as illustrated in Figure 3(b).

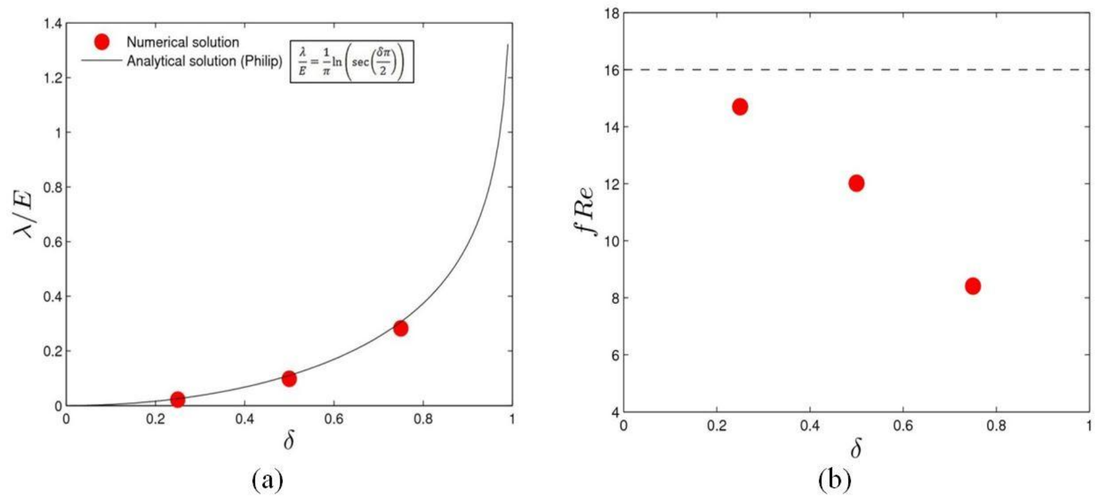

Figure 3. Numerical predictions for: **a** normalized effective slip length; **b** Fanning friction factor-Reynolds number product

Conclusions: By manipulating the superhydrophobicity of such surfaces, the fluid flow in the micro-devices could be potentially enhanced for many applications, including lab-on-a-chip technology, drug delivery, thermal management, etc.

References:

1. Philip JR, Flows satisfying mixed no-slip and no-shear conditions. Journal of Applied Mathematics and Physics (ZAMP) 23 (3):353-372 (1972)