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Demarcating Wetting States in Pressure-Driven Flows by Poiseuille Number

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Abstract : An increase in surface area to volume ratio with a decrease in characteristic length scale, leads to a rapid increase in pressure drop across the microchannel. Texturing the microchannel surfaces reduce the effective surface area, thereby decreasing the pressured drop. Surface texturing introduces two wetting states: a metastable Cassie-Baxter state and stable Wenzel state. Predicting wetting transition in textured microchannels is essential for identifying optimal parameters leading to maximum drag reduction. Optical methods allow visualization only in confined areas, therefore, obtaining whole-field information on wetting transition is challenging. In this work, we propose a non-invasive method to capture wetting transitions in textured microchannels under flow conditions. To this end, we tracked the behavior of the Poiseuille number Po = f.Re, (with f the friction factor and Re the Reynolds number), for a range of flow rates (5 < Re < 50), and different wetting states were qualitatively demarcated by observing the inflection points in the f.Re curve. Microchannels with both longitudinal and transverse ribs with a fixed gas fraction (δ, a ratio of shear-free area to total area) and at a different confinement ratios (ε, a ratio of rib height to channel height) were fabricated. The measured pressure drop values for all the flow rates across the textured microchannels were converted into Poiseuille number. Transient behavior of the pressure drop across the textured microchannels revealed the collapse of liquid-gas interface into the gas cavities. Three wetting states were observed at ε = 0.65 for both longitudinal and transverse ribs, whereas, an early transition occurred at Re ~ 35 for longitudinal ribs at ε = 0.5, due to spontaneous flooding of the gas cavities as the liquid-gas interface ruptured at the inlet. In addition, the pressure drop in the Wenzel state was found to be less than the Cassie-Baxter state. Three-dimensional numerical simulations confirmed the initiation of the completely wetted Wenzel state in the textured microchannels. Furthermore, laser confocal microscopy was employed to identify the location of the liquid-gas interface in the Cassie-Baxter state. In conclusion, the present method can overcome the limitations posed by existing techniques, to conveniently capture wetting transition in textured microchannels.

Keywords : drag reduction, Poiseuille number, textured surfaces, wetting transition
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