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Project Title: Understanding the Influence of Contact Angle Hysteresis on Pressure Drop and Heat Transfer Coefficient in Single Phase Flow

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In this project we are investigating the influence of contact angle hysteresis on the slip length, and consequently its influence on the pressure drop and the heat transfer coefficient in single phase flows (e.g., laminar vs. turbulent and polar vs. non-polar liquids) within a tube.

Contact angle hysteresis (i.e., difference between the advancing contact angle and receding contact angle) of a liquid droplet on a solid surface is a measure of the surface slipperiness to that liquid. In our preliminary work, we tailored the contact angle hysteresis of water (representative polar liquid) and hexadecane (representative non-polar liquid) droplets on glass substrates via silanization. Over the last year, we tailored the contact angle hysteresis on metallic substrates (copper) by systematically tuning various processing conditions (e.g., molecular architecture of the silanes, solvent type, type of catalyzer, molarity of the silane, volume of the catalyzer and the solvent, silanization time, and hydroxylation time) in our acid-catalyzed silanization technique. Then, we measured the advancing and receding contact angles, and contact angle hysteresis, of water and hexadecane on modified copper substrates with ~5 μl droplets. Our results indicate that the contact angle hysteresis of water can be varied from 15° to 70° and contact angle hysteresis of hexadecane can be varied from 12° to 45° on our modified copper surfaces.

Using the modified copper surfaces, we are currently attempting to measure the slip length by employing an ARES Rheometer-G1 parallel plate rheometer consisting of two parallel plates of which the bottom plate (i.e., modified copper) is fixed and the top plate rotates. Thus far, it appears that the sensitivity of the torque transducer is insufficient to distinguish the slipperiness of the different modified copper surfaces. If this continues to be the case, we intend to use contact angle hysteresis as a measure of the slipperiness instead of the slip length.

Further, we are in the process of developing a setup to measure pressure drop and the heat transfer coefficient simultaneously. We are trying to overcome the difficulties in fabrication such as connecting the instrumentation nozzles to the low diameter tubes and aligning the tips of thermocouples in the tubes without noticeably disturbing the fluid flow. Due to these technical difficulties, thus far, reproducible measurements of temperature and heat transfer coefficient in the tubes have been challenging. Consequently, we are still trying to debug our experimental setup by seeking the advice of experts in heat transfer measurement.

Overall, supported by funding from ACS PRF, we expanded the research in our group to include a new direction – design and characterization of novel surfaces for enhanced heat transfer performance. Thee students are finding the interdisciplinary nature of the research – including materials science (fabrication and characterization of surfaces) and heat transfer (development of apparatus and measurement of heat transfer metrics) – very exciting. This is allowing cross-talk between the two fields and we hope that it will bridge the knowledge gaps. Further, as a result of this work, our group got more visibility among the nation's experts on heat transfer. This led to a new unfunded collaboration with the *Energy Transport Research Lab* in University of Illinois at Urbana-Champaign (PI: Prof. Nenad Miljkovic) to characterize the nucleation rate and heat transfer coefficient in dropwise condensation on a wide variety of surfaces (not related to this work).