

Experimental study on interfacial film dynamics of oscillating multiphase micro flows

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Research on interfacial film dynamics, fluid flows, heat and mass transfer in mini/microchannels is a rapidly emerging area in studying micro fuel cells, DNA separation and analysis, valveless micro pumps, micro heat pipes, and in micro-fluidic research. Examples include a high efficient gas-liquid-solid micro fluidics hydrogenation reactor, a promising technique utilizing air-bubble method of catheter locking with anticoagulant at the catheter tip and bactericidal properties at the catheter hub for hemodialysis access, prevention of gas embolism damage in surgery caused by intravascular air bubbles carried in the bloodstream, manipulating microbubbles by ultrasonic waves, cooling of electronics devices using mini/micro heat pipes. To accelerate multiphase catalytic reactions, some treatment producing high interfacial area between the two or three reacting phases is needed. The manipulation of interfacial liquid film thickness between the catalyst surface and reacting gas can further optimize the process. Therefore, it is important to understand the physics of transport processes in a microchannel multiphase flow. It has been found that the surface energy (Surface Wetting Capability) of the wall may have great impact on the interfacial film dynamics when a bubble plug/slug in a liquid flowing in a mini/microchannel. This indicates that the friction of multiphase flows may strongly depend on the wall property in a mini/microchannel. Modeling multiphase fluid flow at the micro-scale with the assumption of simple disjoining pressure and liquid surface tension may not be accurate. It will depend on the interactions between the fluid, gas/vapor, and the surface properties of the wall. Furthermore, due to the complexities of micro scale thermal capillary effects and the aspect ratio of the mini/micro channel, the relationship between the interfacial liquid film thickness, velocity, friction, plug/slug shape, temperature, and properties is not well understood. This paper is to report some fundamental aspects of interfacial film dynamics, heat and mass transfer of plug/slug flows (see Figure 1) in a capillary channel in order to predict and optimize the behavior of multiphase flows in micro spaces.

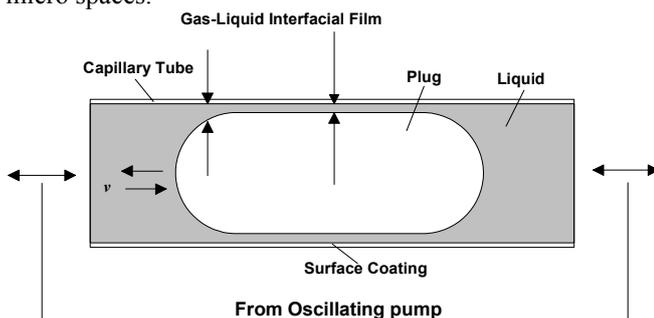


Fig. 1 Schematic of Oscillating Micro Plug Flows

The interfacial film thickness between the plug/slug and the channel wall is measured under different fluid properties, plug/slug velocities, and oscillating frequencies in a horizontal capillary tube utilizing a recently developed optical fringe probing method. The scattered fringes were measured by high speed camera and the calculated spatial frequencies were used to determine the film thickness between the plug and the wall. Utilizing the newly developed measurement technique, the interfacial film dynamics of oscillating plug/slug flows in a capillary channel was investigated. An oscillating plug/slug motion has been investigated and the preliminary results have been obtained as shown in Figure 2. It is found that the pre-wetted interfacial film thickness could not be zero when the bubble is under static state. Also stepwise film thickness variations have been found when the oscillating frequency changes. Furthermore, when the oscillating frequency reaches to 15Hz, periodical film thickness has been found. Further increasing the oscillating frequency will result in wave-like interfacial film thickness variations. It also demonstrated that the oscillating frequencies of the micro plug/slug flows do have significant impact on the interfacial film thickness.

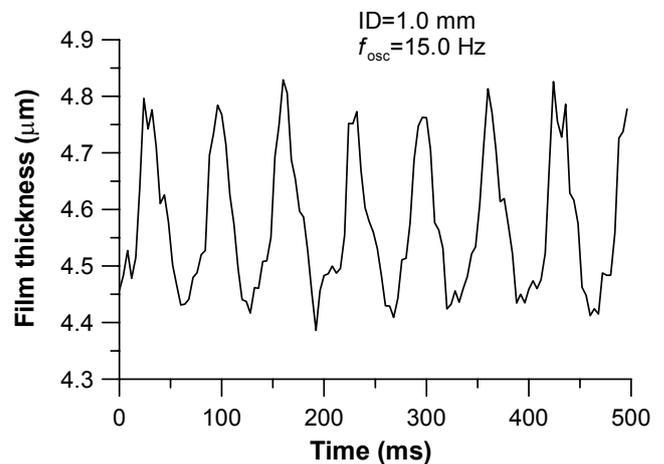


Fig. 2 Measured interfacial film thickness under 15Hz oscillating frequency

Reference

1. Wang XS and Qiu H.-H. (2005) "Fringe Probing of Liquid Film Thickness of a Plug Bubble in a Micropipe," *Measurement Science and Technology*, 16, pp594-600..