Flow Mechanism around a Micropillar with Gas Jet

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ABSTRACT

This study investigated the gas-liquid interaction resulting from the injection of a gas jet into liquid flow, in the presence of a micropillar. The goal was to determine the effect of the micropillar on the bubble formation process and flow patterns; to determine how the various flow patterns influence the liquid flow structure near the micropillar; and to determine if there was potential for mixing enhancement of the flow due to the gas injection process. The gas was injected into the base of a hollow micropillar, through a 50 μm orifice, and passed through a (25 μm wide × 225 μm high) slit/ slit pair into the main channel, where it formed a two phase mixing layer. The D = 150 μm diameter pillar was located along the axial center of the channel and extended along the entire height of the 1500 μm wide by 225 μm high microchannel. Water was introduced into the channel for a Reynolds number range of 100 to 700, where Reynolds number was based on pillar diameter. Nitrogen gas was injected over a range of 0 to 10 ml/min. Six devices were investigated in total, with two devices having single slits at 0-degrees and 180-degrees. The remaining devices had slit pairs at ± 30-degrees, ± 80-degrees, ± 110-degrees, 180-degrees, and 0-180-degrees. Flow visualization using micro particle image velocimetry (*μPIV*) and micro particle tracking velocimetry (*PTV*) were used to elucidate the physics governing the two phase mixing layer. The flow patterns and bubble formation process was characterized, the bubble dynamics (i.e., frequency, size and velocity) was analyzed, and the liquid velocity field studied in the region around the pillar. This encompassed the area from about -2 to 20 pillar diameters along the axial direction from the center of the pillar.

Three modes of bubble formation were observed in which *discrete bubbling* occurred at the slit, an *attached ligament* sheared bubbles from its trailing edge, and a *mixed* mode trapped an *attached ligament* in the center of two parallel bubble streams. The modes were determined to be primarily dependent of changes in the liquid velocity, which caused changes in the liquid-gas inertial force balance and the liquid inertia-shear force balance, both believed to play a role in the determining the mode of bubble formation. While all modes appeared to have a positive effect on mixing, the *discrete bubbling* mode appeared to be the most effective. This was attributed to the characteristic length scale of the bubbles formed. Additionally, the enhancement was most pronounced

at low Reynolds numbers, and this was attributed to the much higher liquid momentum. While fully characterizing the effectiveness of mixing or heat transfer using this technique would require a more direct approach to characterizing mixing, it was determined that the changes to the formation pattern (i.e., bubble size distribution and spacing) and that this technique would me most effective at low Reynolds number flows.