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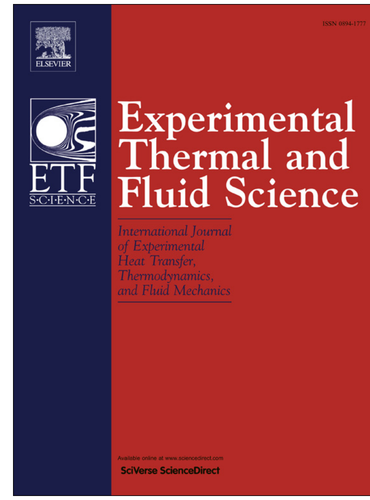

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A Simultaneous Planar Laser-Induced Fluorescence, Particle Image Velocimetry and Particle Tracking Velocimetry Technique for the Investigation of Thin Liquid-Film Flows

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Abstract

A simultaneous measurement technique based on planar laser-induced fluorescence imaging (PLIF) and particle image/tracking velocimetry (PIV/PTV) is described for the investigation of the hydrodynamic characteristics of harmonically excited liquid thin-film flows. The technique is applied as part of an extensive experimental campaign that covers four different Kapitza (*Ka*) number liquids, Reynolds (*Re*) numbers spanning the range 2.3 – 320, and inlet-forced/wave frequencies in the range 1 – 10 Hz. Film thicknesses (from PLIF) for flat (viscous and unforced) films are compared to micrometer stage measurements and analytical predictions (Nusselt solution), with a resulting mean deviation being lower than the nominal resolution of the imaging setup (around 20 μm). Relative deviations are calculated between PTV-derived interfacial and bulk velocities and analytical results, with mean values amounting to no more than 3.2% for both test cases. In addition, flow rates recovered using LIF/PTV (film thickness and velocity profile) data are compared to direct flowmeter readings. The mean relative deviation is found to be 1.6% for a total of six flat and nine wavy flows. The practice of wave/phase locked flow-field averaging is also implemented, allowing the generation of highly localized velocity profile, bulk velocity and flow rate data along the wave topology. Based on this data, velocity profiles are extracted from 20 locations along the wave topology and compared to analytically derived ones based on local film thickness measurements and the Nusselt solution. Increasing the waviness by modulating the forcing frequency is found to result in lower absolute deviations between experiments and theoretical predictions ahead of the wave crests, and higher deviations behind the wave crests. At the wave crests, experimentally derived interfacial velocities are overestimated by nearly 100%. Finally, locally non-parabolic velocity profiles are identified ahead of the wave crests; a phenomenon potentially linked to the cross-stream velocity field.

Key words: Planar laser-induced fluorescence; Particle image velocimetry; Particle tracking velocimetry; Harmonically excited films; Film thickness; Velocity profile