CAPILLARY BRIDGE OSCILLATIONS: NONLINEAR DYNAMICS AND CONTROL

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Active control of radial electric fields and the associated Maxwell stress at the surface of capillary bridges has been used to suppress the Plateau-Rayleigh capillary instability of liquid cylinders in reduced gravity [1]. To facilitate the investigation of the dynamics of capillary bridges in simulated reduced gravity in laboratory-based experiments, we developed Plateau tank systems using immiscible liquids having low kinematic viscosities. The outer bath is an insulating liquid (HFE-7500) and the bridge liquid (a Cesium Chloride solution) was electrically grounded. The stress distribution was controlled using annular disk electrodes concentric with the liquid bridge. The instantaneous amplitude of the fundamental axisymmetric capillary mode of the bridge, designated the (2,0) mode, was optically sensed. Various control strategies and outcomes were investigated. These include suppression of the Plateau-Rayleigh capillary instability [2], active damping of bridge oscillations [3], and active shifting of the natural frequency of the (2,0) mode [4].

In related work [5], large amplitude axisymmetric oscillations of a liquid bridge in a Plateau tank were excited by applying oscillating Maxwell stresses. The modal frequency response was measured by incrementing the drive frequency. In a narrow range of frequencies the response depended on the direction (downward or upward) of the increments in a way consistent with a lumped-parameter model of hysteresis for a weakly-damped oscillator having a mode-softening nonlinearity. The driven mode was the (3,0) mode having three-halves of an axial wavelength. The slenderness of the bridge was selected so that the third harmonic was the natural frequency of a higher-order mode, the (5,0) mode that has five-halves of a wavelength. The response of that mode at the third harmonic also exhibited hysteresis. The observations are strongly suggestive of a mode-coupling term in the potential energy of the surface deformation.

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References

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