Stability Analysis of Thin Liquid Film in a Micro-Pipette

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ABSTRACT

This study is aimed at investigating theoretically the instability of the thin liquid film attached to the inside wall of a micro-pipette through which there exists a steady vapor or gaseous flow. Such an instability, usually called "interfacial instability", is mainly due to the interfacial deformation and surface tension effect accompanied with the liquid-vapor flow, slip boundary condition at the liquid-vapor interface, liquid film thickness, etc.

The linear stability analysis is employed to accomplish the task. The results indicate that the interfacial deformation, basic liquid-vapor flows, slip boundary condition, and liquid film thickness really affect the interfacial instability of the thin liquid film. In the long-wave instabilities, although the liquid-vapor flow and the interfacial slip boundary condition do not change the onset wavenumber, they make the instability shift from the stationary mode to the oscillatory mode. The numerical computation not only demonstrates such a phenomenon but also finds that, in general situations, the basic liquid-vapor flow, or Reynolds number effect, will increase the range of the onset wavenumber of instability. However, the maximum growth rate of instability decreases due to the inertia effect. In addition, it is also found that the wavelength of the unstable disturbances depends proportionally on the film thickness. The interfacial slip boundary condition also changes the onset wavenumber, varying between the one with no-slip boundary condition and that for a stationary liquid film, the classical problem. The frequency of the oscillatory mode of instability has been changed as well.