Experimental study of inclined film flow along periodic corrugations

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ABSTRACT

Liquid films on a flat wall at inclination θ are first destabilized at a critical $Re = 5/6cot\theta$. The instability mode is a long-wave disturbance that travels downstream fast enough to result in a convective instability. We presently investigate how the primary instability is modified when the flat wall is substituted by one with periodic corrugations.

Film flow along a corrugated wall is studied experimentally in a 800 mm long by 250 mm wide channel, whose inclination can be adjusted from 0-50°. Two walls are considered, both with wavelength 12 mm and height 2 mm: in one case the corrugations are purely sinusoidal and in the other they consist of symmetric step-ups and step-downs (orthogonal shape). Multiple conductance probes are installed at different streamwise locations and record time-series of the local free surface elevation[1].

Consistent with previous studies[2], both corrugated walls are found to result in a strong delay of the primary instability of the liquid film, compared to the classical results for flat substrate. Moreover, a significant effect of inclination angle is observed, with the film becoming progressively more stable at higher inclinations. The stabilization also varies with the shape of corrugations: film flow along the orthogonally corrugated wall is more stable at intermediate inclinations.

The above results are clarified and interpreted by the observation of a new instability mode, which manifests as a high-frequency oscillation (≥ 10 Hz) and corresponds to a traveling wave of small wavelength. The new mode appears to be the primary cause of instability at intermediate and high channel inclinations. This observation supports a computational prediction[3], that film flow along sinusoidal corrugations may be unstable not only to long-wave disturbances, but also to disturbances with the wavelength of the wall. It is conjectured that, through an interaction of inlet disturbances with the deformed steady flow, energy is transferred from long-wave modes to the newly observed short wave mode. Given that the latter is expected to remain stable at higher Re, this tentative mechanism may explain the observed enhanced stability of the film.

References

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