Viscous dispersion effects on bound-state formation and self-organization on falling liquid films

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ABSTRACT

Liquid films falling down a vertical wall are always unstable to sufficiently long waves and exhibit a rich dynamics that strongly depends on the Reynolds number Re [1]. A particularly interesting case is that at moderate Re, when the interface of the liquid film, $h(x,t)$ appears to be randomly covered by localized coherent structures, solitary pulses, which are stable and robust. These pulses consist of a nonlinear hump preceded by smaller oscillations controlled by capillary and viscous effects. At sufficiently large distances from the inlet of the film, these localised pulses interact each other as quasi-particles through attractions and repulsions giving rise to the formation of bound states of two or more pulses travelling at the same speed, and separated by well-defined distances.

In this work [2], we examine the interaction of two-dimensional solitary pulses on falling liquid films. We make use of an averaged model that includes the usually omitted second-order viscous effects in the long-wave expansion [3]. These effects originate from the streamwise momentum equation and tangential stress balance, and play a dispersive role affecting primarily the shape of the capillary ripples in front of the solitary pulses. They turn out to be crucial when describing the pulse interaction that eventually gives rise to the formation of bound states. By developing a coherent-structures theory that assumes weak interaction between the pulses [4], we are able to theoretically predict the pulse-separation distances for which bound states are formed. Our theoretical predictions are in very good agreement with computations of the fully nonlinear system. On the other hand, by studying numerical strong interactions between pulses we find an emerging steady oscillating state for the pulse separation length that is significantly affected by viscous dispersion. We also demonstrate that the presence of bound states allows the film free surface to reach a self-organized state that can be statistically described in terms of a gas of solitary waves separated by a typical mean distance and characterized by a typical density.

REFERENCES

[1] H-C. Chang, *Wave evolution on a falling film.* Annu. Rev. Fluid Mech. **26**, 103 (1994).

[2] M. Pradas, D. Tseluiko, and S. Kalliadasis *Rigorous coherent-structure theory for falling liquid films: Viscous dispersion effects on bound-state formation and self-organization.* Phys. Fluids (submitted).

[3] C. Ruyer-Quil and P. Manneville, *Improved modeling of flows down inclined planes.* Eur. Phys. J. B **15**, 357 (2000).

[4] C. Duprat, F. Giorgiutti-Dauphiné, D. Tseluiko, S. Saprykin and S. Kalliadasis *Liquid film coating a fiber as a model system for the formation of bound states in active dispersive–dissipative nonlinear media.* Phys. Rev. Lett. **103**, 234501 (2009).