Modeling film flows down fibers

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Besides their importance for engineering applications (*e.g.* evaporators or chemical reactors), the interest of falling liquid films mainly stems from the fact that their evolution is tractable to thorough theoretical analysis.

We consider here the evolution of axisymmetric waves on a liquid film falling down a vertical fibre. This problem has attracted numerous recent works [KDB01, CM06, SCMG06, RL06], a situation that is probably due to the large panel of wave regimes observable in the experiments, e.g. noise-driven dynamics characterized by solitary wave interaction, regular "drop-like" wave patterns, spatial modulation of multi-hump solitary-like wavetrains excited by a periodic forcing at inlet, bi-periodic wave patterns made of a repetition of merging and wave radiations, etc. This variety of nonlinear phenomena arises from the non-trivial interaction of the Rayleigh-Plateau instability mechanism in cylindrical geometry, and the classical Kapitza instability of falling films.

Despite a continuous modeling effort, low-dimensional models available in literature either neglect inertial effects [KDB01, CM06], or underestimate streamwise viscous terms that modify the wave dispersion [SCMG06], or consider only small curvature effects [RL06]. We develop a weighted residual-method that enable to overcome the above cited limitations. The obtained model consist in two evolution equations for the film thickness h and the flow rate q. Linear stability analysis of the dispersion relation of the model precisely recover all feature of an Orr–Sommerfeld analysis of the basic linearized equations. In particular, the prediction of the onset of an absolute instability is in excellent agreement with both Orr–Sommerfeld analysis and experimental data [DRQKGD07]. Traveling-wave solutions to the approximate model compare well to the experimental profiles, whereas numerical simulations of the spatial response of the film to an harmonic inlet excitation recover the multi-hump patterns observed experimentally. A strong influence of inlet forcing amplitude on the selection of the experimental wavy pattern is also observed in our simulations.

References

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