66th Annual Meeting of the APS Division of Fluid Dynamics
24-26 November 2013, Pittsburgh, Pennsylvania, U.S.A.

The stabilizing mechanism of surfactants in falling films

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Abstract

We investigate the stabilizing effect of surfactants in gravity-driven liquid films flowing down inclined surfaces. To this end, we consider the Navier-Stokes equations along with advection-diffusion equations and chemical kinetic fluxes for the surfactant transport and derive an analytical solution by expanding in the limit of long-wave disturbances. We present a physical mechanism for the role of a surfactant of arbitrary solubility. The stabilizing effect is due to an interfacial concentration gradient which is in-phase with the interfacial deformation inducing Marangoni stresses driving liquid from the crest to the trough. The strength of the interfacial concentration gradient is shown to be maximum for an insoluble surfactant and to decrease with increasing surfactant solubility. The decrease is explained in terms of the phase of mass transfer between interface and bulk, which mitigates the interfacial flux by the flow perturbation, and leads to the attenuation of Marangoni stresses.

The research project is implemented within the framework of the Action «Supporting Postdoctoral Researchers» of the Operational Program "Education and Lifelong Learning" (Action's Beneficiary: General Secretariat for Research and Technology), and is co-financed by the European Social Fund (ESF) and the Greek State.