Stability of thin liquid film flows over a uniformly heated slippery substrate under Heat Flux boundary condition

Anandamoy Mukhopadhyay* and **Amar Gaonkar***

* *Department of Mathematics, Vivekananda Mahavidyalaya (The University of Burdwan), West Bengal 713103, India.*

** *Department of Mechanical, Materials and Aerospace Engineering, IIT Dharwad, Karnataka-580011, India.*

Abstract. We investigate the stability of gravity-driven Newtonian, thin liquid film falling down a uniformly heated slippery inclined plane. The rigid inclined plane is not thermally insulated as considered by most authors ([1]- [3]) in their study. In real situation heat losses to the ambient air at the solid-air interface. Consequently, we have considered Heat Flux (HF)/mixed-type boundary condition as the thermal boundary condition on the rigid plate. This boundary condition involves the heat flux from the rigid plate to the surrounding liquid and the heat losses from the wall to the ambient air. Using long-wave expansion method we construct a highly nonlinear evolution equation in terms of the film thickness at any instant. Using normal mode approach the linear study reveals the onset of instability. Weakly nonlinear study demarcates the different stable/unstable zones and their variations with the variation of the wall film Biot number B_w and the slip length δ, associated with the heat losses at the solid-air interface and the slippery effects of the rigid substrate respectively. Finally, the numerical simulation of the evolution equation is performed using Crank-Nicolson scheme over a periodic domain. It confirms the results obtained by the linear and the weakly nonlinear study.

Introduction

Hydrodynamical stability of thin liquid film flows down a uniformly/non-uniformly heated vertical/inclined plane is a fascinating problem. Recently, few works ([1]- [3]) are published, where the rigid substrate is considered to be slippery, since in laboratory researchers are engaged to prepare hydrophobic/superhydrophobic surfaces to fulfill the demand of industry. Now the thermal boundary condition considered by the researchers ([1]- [3]), for the thin liquid film flow problem over a heated slippery substrate is of specified temperature (ST) boundary condition / Dirichlet condition, where the rigid substrate is assumed to be of thermally insulated and therefore no heat losses at the solid-air interface. In real situation there exists no such insulation that prevents heat loss to the ambient air. In the proposed model, our aim is to discuss the effect of slip length on the dynamics and the stability of thin liquid film flow, over a uniformly heated slippery substrate, under the HF boundary condition.

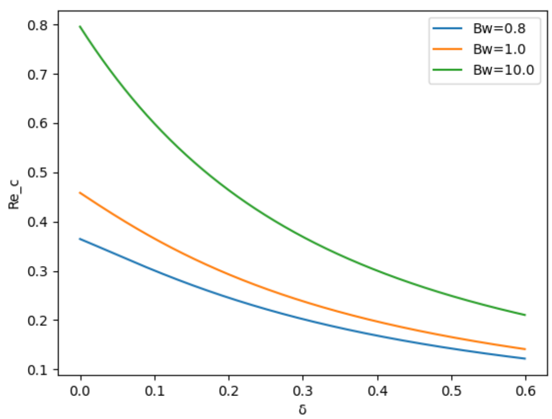

Figure : Variation of critical Reynold's number with the variation of slip length and for typical values of wall film Biot number Bw = 0.8, 1.0, 10.0.

Results and Discussions

As the wall film Biot number increases, the Re_c also increases. It confirms the stabilizing role of wall film Biot number B_w. Also, as the slip length δ increases, Re_c decreases. It shows the destabilizing role of the slip length, found by the linear stability analysis.

References

[1] Samanta A. (2020) Non-modal stability analysis in viscous fluid flows with slippery walls. *Phys. Fluids* **32**:064105.

[2] Chattopadhyay A., Desai A. S., Gaonkar A., Barua A. K. and Mukhopadhyay A. (2021) Weakly viscoelastic film on a slippery slope. *Phys. Fluids* **33**:112107.

[3] Chattopadhyay A., Mukhopadhyay A. and Barua A. K. (2021) Thermocapillary instability on a film falling down a non-uniformly heated slippery incline. *Int.J. Non-linear Mech.* **133**:103718.