Spatial stability of a heated falling film down slippery plane

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We have conducted a study to analyse the linear stability of a liquid film flowing down a slippery inclined plane. The inclined plane is maintained at a constant temperature, higher than the ambient. Apart from surface tension, all the properties of the liquid are considered to be constant. To capture the surface mode/H mode instability analytically at low Reynolds number, long-wave approximation approach is employed. Figure 1(a) shows the comparison of neutral stability curve in (Re, k_x) plane obtained from third-order and fifth-order long-wave approximations, Padé approximation [1,2] and numerical solution when $We = 60$, $\beta = 0.02$, $Bi = 1$, $Pr = 6.5$, $Ma = 7$, $k_z = 0$. Here, We, Bi, Pr, Ma, Re, β, k_x and k_z, represent Weber number, Biot number, Prandtl number, Marangoni number, Reynolds number, nondimensional slip length, streamwise wavenumber and spanwise wavenumber respectively. It can be observed that long-wave approximate solutions start deviating from the numerical result at high wave number range. However, the numerical result is captured more accurately by the Padé approximate solution compared to the long-wave ones. The spatial growth rate for P mode is numerically calculated by solving a coupled eigenvalue problem using Chebyshev spectral method[3]. Figure 1(b) depicts the variation of spatial growth rate ($-k_i$) for thermocapillary P mode for different values of Prandtl number when $Ka = 240$, $k_z = 0.5$, $Re = 20$, $\beta = 0.02$, $B = 1$, $M = 20$. Here, Ka indicates the Kapitza number, $B = Bi(1 + 2\beta)^{1/3}(2Re)^{-1/3}$ and $M = Ma(1 + 2\beta)^{1/3}(2Re)^{2/3}$. It is observed that Prandtl number exerts a destabilizing effect on the thermocapillary P mode of instability. However, we have not noticed any significant effect of Prandtl number on other modes of instability.

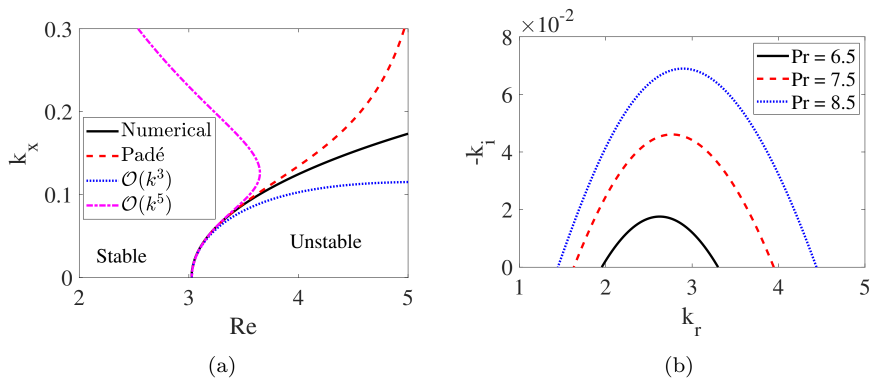

Figure 1: (a) Neutral stability curve for H mode instability in (Re, k_x) plane. (b) Evolution of spatial growth rate for P mode instability in (k_r,$-k_i$) plane for different values of Pr.

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