
On the stability of the laminar boundary layer beneath a Stokes wave

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The linear stability of the laminar boundary layer flow of a Stokes wave in deep waters is investigated by means of a 'momentary' criterion of instability for unsteady flows. In the parameter range investigated, it is found that the flow is stable to 2-D perturbations. The least stable eigenmode of the resulting Orr-Sommerfeld spectrum attains its maximum beneath the boundary layer of the Stokes wave. Moreover, an analysis of the associated pseudospectrum indicates that the laminar flow when modified by imperfections is unstable due to the non-normality of the Orr-Sommerfeld operator, and the unstable pseudo-eigenmodes tend to peak within the boundary layer. The laminar flow of the Stokes wave is also stable to 3-D streamwise-independent perturbations. Instability is observed for the laminar flow with imperfections. The associated unstable pseudo-eigenmodes are streamwise vortical rolls similar to Langmuir cells. The laminar boundary layer flow of a Stokes wave appears to be stable to infinitesimal perturbations, but it may likely be unstable to finite perturbations, as in Poiseuille pipe flows. The present results are supportive of the recent experimental evidence of spontaneous occurrence of turbulence beneath unforced non-breaking surface waves.

