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Effect of Gas Boundary Layer on the Stability of a Radially Expanding Liquid Sheet

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Abstract : Linear stability analysis is performed for a radially expanding liquid sheet in the presence of a gas medium. A liquid sheet can break up because of the aerodynamic effect as well as its thinning. However, the study of the aforementioned effects is usually done separately as the formulation becomes complicated and is difficult to solve. Present work combines both, aerodynamic effect and thinning effect, ignoring the non-linearity in the system. This is done by taking into account the formation of the gas boundary layer whilst neglecting viscosity in the liquid phase. Axisymmetric flow is assumed for simplicity. Base state analysis results in a Blasius-type system which can be solved numerically. Perturbation theory is then applied to study the stability of the liquid sheet, where the gas-liquid interface is subjected to small deformations. The linear model derived here can be applied to investigate the instability for sinuous as well as varicose modes, where the former represents displacement in the centerline of the sheet and the latter represents modulation in sheet thickness. Temporal instability analysis is performed for sinuous modes, which are significantly more unstable than varicose modes, for a fixed radial distance implying local stability analysis. The growth rates, measured for fixed wavenumbers, predicated by the present model are significantly lower than those obtained by the inviscid Kelvin-Helmholtz instability and compare better with experimental results. Thus, the present theory gives better insight into understanding the stability of a thin liquid sheet.

Keywords : boundary layer, gas-liquid interface, linear stability, thin liquid sheet
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