INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Rayleigh-Taylor instability in viscosity stratified fluid medium

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SHORT ABSTRACT

In the present work, study of Rayleigh-Taylor instability in viscosity stratified fluid medium is carried out. The instability is studied for two dimensional rectangular as well as axisymmetric coordinate configurations using numerical simulations. In both the configurations, two viscous fluid layers, a heavier fluid layer is superposed over a lighter fluid layer, are sandwiched between two parallel isothermal horizontal solid walls. Out of the two walls, one wall is isothermally heated, while the other wall is isothermally cooled. In particular, the effect of stratification due to viscosity varying exponentially with temperature on the instability is studied. Marangoni effect on the instability is studied under the influence of viscous stratification for both the configurations. The studies carried out in the present work consist six parts.

In the first part, Rayleigh-Taylor instability is studied in viscosity stratified fluid layers in 2-D rectangular coordinate configuration. Study of viscosity stratification effect on the instability is carried out for exponentially varying viscosity with temperature. Effect of different parameters such as viscosity ratio, temperature ratio, Weber number, Prandtl number and hot and cold wall locations on the instability is studied under the influence of viscosity stratification. For variable viscosity, spike deformation is found to be higher and spike movement is found to be faster compared to that of constant viscosity. Increase in viscosity ratio is found to show reduced deformation of spike and stabilizing effect on the instability. Increase in temperature ratio is found to show destabilizing effect on the instability with irregular spike-arm structure for higher temperature ratios. For top heated configuration, the spike deforms more and moves faster than that of bottom heated configuration. The instability is found to be unaffected by variation of Prandtl number. For Weber number less than critical value, the configuration does not undergo instability. Beyond the critical value, increasing Weber number shows destabilizing effect on the instability. A range of Weber numbers exist in which spatial periodicity of the instability is higher than spatial periodicity of the initial perturbation, unlike for the other remaining ranges of Weber number. In the second part, the effect of functional variation of viscosity with temperature on the instability is studied in 2-D rectangular coordinate configuration for four types of viscosity variations, which are constant, linear, power law and exponential variations. The study of effect of functional variation of viscosity on the instability is carried out for various viscosity ratios and density ratios. Type of viscosity variation shows strong effect on the instability at low viscosity ratios and low density ratios. At high viscosity ratios, the spike is formed as a fluid column structure, irrespective of type of viscosity variation. At high density ratios, viscosity variation effect on the instability is found to be smeared out in the dominance of inertial forces. Overall, rate of spike movement is in decreasing order of sequence of exponential, linear, constant and power law variations, for all viscosity ratios and density ratios. In the third part, Marangoni effect due to temperature varying surface tension on the instability is studied in 2-D rectangular coordinate configuration. Marangoni effect is studied for three types of functional dependencies of surface tension with temperature, which are constant, linear and parabolic dependencies. Effect of Weber number and Froude number on the instability is studied in the presence of Marangoni effect. Rate of spike movement for the three types of surface tension dependencies is in increasing order of sequence of constant, parabolic and linear dependencies as overall effective surface tension decreases in the above sequence. Critical value of Weber number is found, below which the configuration does not undergo instability, and beyond which increasing Weber number shows destabilizing effect on the instability. Increasing Froude number shows stabilizing effect on the instability. Critical Froude number is found above which the configuration is stable.

In the fourth part, Rayleigh-Taylor instability is studied in viscosity stratified fluid layers in axisymmetric configuration. Viscosity stratification effect on the instability is studied for viscosity varying exponentially with temperature. Effect of viscosity ratio, temperature ratio, Prandtl number, Weber number and hot and cold wall locations on the instability is studied in the presence of viscosity stratification. For variable viscosity, the configuration becomes more unstable and spike undergoes larger deformation compared to that of constant viscosity. It is found that increasing viscosity ratio shows stabilizing effect. Increasing temperature ratio shows destabilizing effect on the instability and irregular spike-skirt structure is formed for high temperature ratios. In top wall heating configuration, formation of mushroom shaped spike occurs earlier compared to that in bottom wall heating configuration. Prandtl number variation is found to show negligible effect on the instability. For Weber number less than critical value, the configuration does not undergo instability, beyond which increasing Weber number shows destabilizing effect on the instability. In the fifth part, effect of functional variation of viscosity with temperature on the instability is studied in axisymmetric configuration for four types of viscosity variations, which are constant, linear, power law and exponential variations. The study of effect of functional variation of viscosity on the instability is carried out for various viscosity ratios and density ratios. The functional variation of viscosity is found to show strong influence on the instability at low viscosity ratios and low density ratios. For high viscosity ratios as well as high density ratios, dynamics of instability becomes independent of type of viscosity variation. Rate of spike movement is in increasing order of sequence of power law, constant, linear and exponential variations due to that the overall effective viscosity is in the decreasing order of the above sequence. In the sixth part, Marangoni effect due to temperature varying surface tension on axisymmetric Rayleigh-Taylor instability is studied in viscous stratified fluid layers. Marangoni effect is studied for constant, linear and parabolic variations of surface tension with temperature. The instability is also studied for the effect of Weber number, temperature ratio and Froude number in the presence of Marangoni effect. Rate of spike movement is lowest for parabolic and highest for linear dependency of surface tension. With increasing temperature ratio up to a certain value, rate of spike movement increases, beyond which it decreases. For temperature ratio more than critical temperature ratio, the configuration does not undergo instability. The critical Weber number is found below which the configuration is stable, and beyond the critical value, increasing Weber number shows destabilizing effect on the instability. For Weber number approaching infinity, surface tension approaching zero, multiple roll up structures form on the stem of the spike. Increase in Froude number shows stabilizing effect on the instability, and beyond critical value of Froude number the configuration is found to be stable.