ABSTRACT

A theoretical analysis has been carried out to investigate the linear stability of compressible mixing layers. Two models of temperature profiles of reacting mixing layers; one based on an algebraic model and the other based on flame sheet approximation have been used. Inviscid and viscous linear stability analyses have been carried out. The temporal and spatial growth rates for adiabatic (isoenergetic), endothermic and exothermic processes assuming parallel flow and normal mode decomposition have been studied. It has been found that direct spatial evaluation of growth rates is preferable to those obtained using Gaster's transformation.

In the present work, non-isentropic condition has been used in developing the stability equations, which is an improvement over isentropic condition used by previous research workers. The subsonic and transonic range of Mach numbers are considered in the present study. Since inviscid instability is the primary instability mechanism, in the range of Mach numbers considered, local conditions for the existence of inflectional profiles are given for the subsonic and supersonic disturbances, in an inviscid set-up. It has been found that the flow must remain locally homentropic for the existence of inflectional subsonic instability. The flow should be locally supersonic over a part of the domain for the existence of supersonic instability mode. It has been observed that unlike subsonic disturbances, supersonic disturbances show

non-uniqueness in their modes of oscillations. Estimates on the bounds of the growth rates in the form of an extension of the semi-circle theorem are presented for the non-homentropic mixing layers under consideration. It has been found that the bounds on temporal growth rates under non-homentropic, non-isentropic considerations are 10^{-4} times those of growth rates predicted by isentropic condition. This order of magnitude difference would require significantly more precise and accurate experimental set-up to compare successfully the recordable instability signals with theoretical data. It has been found that endothermic processes retard the growth rates while exothermic processes enhance them. These results are in contrast with the results under isentropic condition reported by earlier workers. An increase in Mach number enhances the growth rate.

The algebraic model predicts the existence of an isolated neutral point at a wavenumber of 0.6. The existence of double and triple bifurcation points are observed from inviscid analysis, where the three modes correspond to a jet mode, a fully developed mixing layer mode and a mixed mode (mixture of jet and mixing layer mode). Viscous stability studies show that viscosity has an uniform damping effect on the growth rates upto an extent of 10% of the inviscid values. Also, at wavenumber of 0.6, viscous studies show that there does not exist any isolated neutral point. The effects of exothermic process and an increase in Mach number are to enhance the viscous growth rates, similar to those observed in the inviscid case. Both the inviscid and the viscous results indicate that mixing layer flows are convectively unstable and that endothermic processes enhance the convective instability behaviour. This is in accordance with the published results.

Under viscous flow assumption, asymptotic expressions of neutral curves for two models of temperature profiles have been obtained. With increase in Mach number and for exothermic processes, the instability zones in the neutral curves widen, indicating that the flow tends to be more unstable. The asymptotic results largely confirm the inviscid and viscous results regarding exothermic process and Mach number rise.

The linear stability analysis has been extended to weakly non-linear analysis with the aim of studying the spatio-temporal development of mixing layers. This is done using; (i) absolute convective instability analysis and (ii) amplitude evolution model without parallel flow assumptions. Absolute-convective instability analysis considers breakdown of linear wavepackets. Using a single operator in stream function form to represent two-dimensional disturbances in compressible flows, including non-homentropy the impulse response behaviour has been studied. The two separate models representing reacting temperature profiles for the flow, having insignificant density stratification are used to study the three commonly occurring modes of oscillations in developing mixing layers. A comparative study of these models shows that in the background of dominant convective instability there exists local pockets of absolute instability in the fully developed mixing layer mode of oscillation. This represents the "engulfing" mechanism of the roll-up processes. Amplitude evolution equations are developed using multiple scaling technique, without the normal mode and parallel flow assumptions. It is observed that the amplitude of the disturbance is exponentially bounded in its growth.

The thesis comprises of four chapters, namely, Introduction and Literature survey, Analysis, Results and Discussion and Conclusions. In the first chapter the problem under investigation is introduced and the literature on stability analysis of shear layers in general and reacting mixing layers in particular is surveyed. The linear inviscid and viscous analysis is dealt in the second chapter. The governing equations are formulated for the inviscid and viscous problems and various inviscid stability criteria are posed for subsonic and supersonic disturbances. The forms of the asymptotic neutral curves are analysed. Weakly nonlinear analysis is made in the framework of absolute-convective instabilities and amplitude evolution equations. The third chapter deals primarily with all the results obtained using various analyses. The conclusions are summarised in the fourth chapter.

KEY WORDS

Nonisentropic, non-homentropic, compressible mixing layers, spatio-temporal development, exothermic and endothermic processes, linear stability analysis, local stability

existence criteria, semi-circle theorem, computed spatial and temporal growth rates, inviscid, viscous, weakly non-linear analysis, absolute and convective instabilities, amplitude evolution equations.