Abstract of Thesis

Stability and transition of the boundary layer from laminar to turbulent is a century-old problem and difficult to predict. Earlier research has shown that the secondary mechanism followed by nonlinear interaction is the most viable path to transition in low environmental disturbances. However, there has been little research on the secondary mechanism and the nonlinear process, especially for high-speed flows, and current understanding still requires attention. High-speed flows are always subjected to high temperatures due to shock formation and friction between surface and fluid. High temperature alters the gas composition, affecting the flow stability. The high temperature at the surface is hazardous, and thermal protection at the outer surface is used, usually made up of ablative materials. Ablative material ejects gaseous products as it is subjected to heating. The ejected gaseous products affect the flow stability. This dissertation studies the effect of real gas and surface blowing (loosely replicate ablation process) on the secondary instability and nonlinear interaction. The research work is subdivided into three primary objectives: secondary instability with surface blowing for flow over a flat plate and a blunt cone, secondary instability for a real gas, and nonlinear modal interaction.

In the first objective, the effect of surface blowing, which loosely replicates the ablation process, is studied on the secondary instability. Mean flow over a flat plate is solved using the boundary layer equations, while the mean flow over a blunt cone is solved using an in-house shock-fitting Direct Numerical Simulation code. In the second objective, the real gas effect on secondary instability has been studied. The real gas is assumed to be in thermochemical equilibrium, where the air is considered a mixture of perfect gases in local thermal and chemical equilibrium. The last objective studies the nonlinear modal interaction for a wave triad. The wave triad consists of two unstable second mode waves and a difference mode wave such that the triad satisfies Craik's resonance condition. The nonlinear interaction formulation is performed using the method of multiple scales. A detuning parameter is used for wavenumbers, whereas frequencies are assumed to be perfectly tuned, satisfying the resonance condition.