PhD Dissertation Defense Announcement
Mechanical and Aerospace Engineering Department
University of Texas at Arlington

ANALYTICAL AND EXPERIMENTAL STUDIES ON MIXING IN SUPERSONIC FLOWS

By

VIJAY GOPAL

Thesis Advisor: Professor Dr. Luca Maddalena

2:30 pm C.T., Monday, 30th November 2020

Click **here** to join Microsoft Teams

Abstract

Introducing streamwise vortices and tailoring their interactions for mixing enhancement in supersonic flow is the primary motivation of this study. Leveraging the research performed in the group at the Aerodynamics Research Center, systematic experimental studies on mixing enhancement are performed by tailoring selected modes of streamwise vortex interactions with the aid of an in-house developed reduced order method, *VorTX*. This method utilizes the lifting line-vortex theory to perform rapid simulations of vortex interactions. One of the difficulties associated with scaling the flow-physics to higher Mach numbers ($M > 4$) arise from the strong influence of the singularities along the Mach cones that results in physically inconsistent solutions. In this work, a fundamental analytical and numerical analysis on the influence of vorticity distribution in linearized supersonic flow is carried out and by understanding the mathematical and physical nature of the origin of the singularities, proposed candidates for vorticity distribution to eliminate singularities while retaining the irrotational characteristic of the flow are explored. A novel successful formulation is presented and has resulted in a featured journal article in *Physics of Fluids*.

Experimental studies on supersonic mixing were conducted for two selected modes of vortex interactions with the aid of the new theoretical findings. One is the merging of two co-rotating vortices and the other is the non-merging case where the vortices interact but do not merge. Quantitative mixing measurements in supersonic flow were performed using the Filtered Rayleigh Scattering (FRS) technique. To enhance the reliability of the FRS measurement technique, a new method to minimize the systematic errors is proposed for a canonical case of rectangular jet in supersonic flow. Specifically, the focus was on the errors that arise from the assumptions made in FRS experiments on the invariance of total number density as well as the Doppler shift effect. A model that is based on the integration of the equations of motions with tailored turbulence closure, for a rectangular jet in supersonic air flow, was developed in order to augment the understanding and to guide design of FRS experiments and to evaluate the systematic errors in helium mole-fraction measurements.