UNIVERSITY OF MARYLAND

THE BURGERS PROGRAM FOR FLUID DYNAMICS
FLUID DYNAMICS REVIEWS SEMINAR SERIES

LINEAR, NONLINEAR, AND TRANSITIONAL DYNAMICS OF SECOND-MODE INSTABILITY

Friday, September 25, 2020 | 11am - 12pm
Zoom link: https://umd.zoom.us/j/4487374796
Meeting ID: 448 737 4796

Guest Speaker

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ABSTRACT

Hypersonic technology plays an important role in high-speed propulsion for both commercial and military applications. A major challenge in the design of high-speed vehicles is the prediction and control of boundary layer transition. Transitional and turbulent boundary layers induce increased wall-loading on the vehicle, with detrimental effects on propulsive efficiency. The focus of this seminar is our research on various regimes of evolution of a key instability that induces transition in hypersonic boundary layers (HBLs) - the second-mode or Mack-mode. The first regime involves linear evolution of the second-mode, which we analyze using a thermo-acoustic framework. This has helped identify an intricate structure within this instability wave, including vortical cells and trapped acoustic monopoles, along with thermal precursors to transition. The nonlinear regime is studied using perturbation analysis and modal decompositions, that identify new regions of instability growth, beyond those predicted by linear theory. These regions make the second mode susceptible to secondary instabilities, and eventual breakdown. High-fidelity simulations are then utilized to simulate the breakdown of the second-mode, resulting in fully turbulent HBLs, with a focus on frequency broadening within the fundamental instability, and near-wall topology resulting from the turbulent flow. The evolution of the second-mode in this regime is highly dependent on the wall temperature, which determines the statistical properties of near-wall structures that result in peak skin-friction and heat-transfer.

BIO

S. Unnikrishnan obtained his Ph. D. in aerospace engineering from The Ohio State University in 2016, with a thesis on developing techniques to identify noise source mechanisms in supersonic jets. Ongoing development of this work has resulted in computationally inexpensive far-field noise prediction tools and acoustic models for circular and rectangular jets. As a post-doctoral researcher at OSU, he worked on an energy-based approach that identifies Kovasznay-type modes in hypersonic transitional boundary layers, to yield physical insights into the behavior of first- and second-modes of instability. High-fidelity simulations are an integral part of these studies, and are often complemented by state-of-the-art analysis techniques, involving modal and statistical tools. Current research includes application of hydrodynamic stability theory using operator-free approaches for global instability studies in high-speed flows, scale-resolved simulations and linear analyses of supersonic inlets, and hydrodynamic and acoustic evaluation of heated, imperfectly expanded jets.

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