# Mechanical Engineering Dissertation Defense

## Analysis of Low-frequency Unsteadiness in Separated Flows Using Vorticity Variants

**School for Engineering of Matter, Transport and Energy**

**Sijie Huang**

**Advisor:** Jeonglae Kim

## Abstract

Various separated flows exhibit low-frequency unsteadiness (LFU), characterized by oscillations at time scales much longer than the primary flow dynamics (such as vortex shedding and convection in the boundary layer). Despite being secondary in amplitudes and frequencies compared to the primary flow dynamics, the LFU is practically important since it is usually manifested as long-time modulation in integral quantities, such as heat flux, drag force, pressure loading, all of which have significant implications for the performance and robustness of the underlying flow device/system. However, the physical mechanism responsible for LFU is still not fully understood. Existing theories, models, and descriptions are often qualitative and heuristic, leading to ongoing debates among them.

In this dissertation work, a reduced-order analysis framework is developed to characterize the LFU of separated flows. The framework interprets LFU as a consequence of kinetic energy imbalance in the separation bubble. The rotational form of the Navier--Stokes equations, which involves several terms derived from vorticity (and hence vorticity variants), is used to formulate the kinetic energy evolution within the separation bubble, motivated by their connection to vorticity transport and vortical structures. Temporal low-pass filtering is employed to extract LFU from the background flow for analysis

The developed framework is applied to three types of separated flows, including laminar wake flow, shock/turbulent boundary layer interactions, and transitional flow over a backward-facing step. The correlations between LFU and kinetic energy are demonstrated, and the dynamics of kinetic energy evolution are analyzed. The frequency of LFU is estimated, and a data-driven modeling technique is employed to discover models describing LFU.

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Zoom Link: https://asu.zoom.us/j/85866328991

Arizona State University