Mechanical & Industrial Engineering
UNIVERSITY OF TORONTO

MIE498H1: Research Thesis 2025-2026

Supervisor	Pierre Sullivan
Supervisor email	pierre.sullivan@utoronto.ca
Number of Positions	1
Open to	Mechanical Engineering Students
Term Offered	Full-year
Research Area	Thermofluids
Research Topic	Unsteady Reynolds-Averaged Navier-Stokes (URANS) Simulations of Flow Past a Single Cube at Various Angles of Attack

Project Description

This thesis proposes to investigate the unsteady aerodynamic characteristics of flow past a single cube at various angles of attack using Unsteady Reynolds-Averaged Navier-Stokes (URANS) computational fluid dynamics simulations. The study will systematically analyze how different orientations of the cube relative to the incoming flow influence key aerodynamic phenomena, including vortex shedding patterns, flow separation and reattachment, pressure distributions, and overall force coefficients. Using commercial CFD software, an unstructured computational mesh will be generated around the cube with fine resolution near critical regions, and multiple turbulence models (Spalart-Allmaras, SST k-ω, and Realizable k-ε) will be evaluated to determine their accuracy in capturing the complex unsteady flow structures. The methodology involves applying appropriate boundary conditions, implementing second-order spatial discretization schemes with small time steps to resolve transient features, and conducting comprehensive post-processing to extract aerodynamic coefficients, visualize vortex structures using Q-criterion, and analyze velocity fields and turbulence kinetic energy distributions. Expected outcomes include a detailed understanding of how the angle of attack affects cube aerodynamics, characterization of wake structures and flow physics, comparative assessment of turbulence model performance, and practical insights for engineering applications involving bluff body flows such as building design and urban wind environments. This research will contribute to the fundamental knowledge of fluid dynamics while providing valuable guidance for structures exposed to variable wind loading conditions. It will demonstrate the capabilities and limitations of the URANS methodology for simulating unsteady turbulent flows around geometrically simple yet aerodynamically complex bluff bodies.

Application Instructions	Please submit CV and unofficial transcript to pierre.sullivan@utoronto.ca