MIE498H1: Research Thesis 2025-2026

Supervisor	Pierre Sullivan
Supervisor email	pierre.sullivan@utoronto.ca
Number of Positions	1
Open to	Mechanical and Industrial Engineering Students
Term Offered	Full-year
Research Area	Thermofluids
Research Topic	Development of Laser-Based Flow Visualization Techniques for Pitching Airfoil Aerodynamic Analysis

Project Description

This thesis project will develop and implement a low-power laser flow visualization system to support ongoing PhD research on pitching airfoil aerodynamics, providing the undergraduate student with hands-on experience in experimental fluid mechanics while generating valuable preliminary data for advanced PIV measurements. The student will take ownership of optimizing laser-based visualization techniques, particularly focusing on particle streak or smoke wire methods, for a predefined pitching airfoil geometry to map dynamic flow separation, reattachment behavior, and unsteady wake characteristics across oscillation frequencies and amplitudes. Building on established research showing that laser visualization techniques can effectively capture vortex dynamics—where low pitching rates generate numerous small-scale vortices while high pitching rates produce fewer but larger vortices with scales approximately one-fourth the chord length—the student will develop methodologies to visualize separation boundaries, wake vortices, and boundary layer interactions that are critical for understanding pitching airfoil performance. Key technical objectives include mastering laser safety protocols through university training, optimizing laser sheet optics and particle seeding systems, establishing reliable flow visualization methodologies that complement existing PIV capabilities, and developing image analysis techniques to characterize unsteady flow structures. The project emphasizes practical problem-solving skills including basic machining for fixture modifications, optical alignment, and comparative analysis with traditional visualization methods, while maintaining realistic scope through the use of commercially available laser components and built-in flexibility to scale between qualitative flow visualization and semi-quantitative measurements based on technical challenges encountered. The undergraduate's characterization of vortex shedding patterns, separation dynamics, and wake structure development will directly support the PhD student's quantitative PIV research by identifying optimal measurement locations, revealing unexpected flow phenomena, and validating experimental setup reliability for high-speed unsteady flows, creating a natural mentorship structure that advances both fundamental understanding of pitching airfoil aerodynamics and practical laser-based measurement techniques.

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