Aerodynamic flow control of flow separation on the NASA hump

Proposed supervisors: Professor Julio Soria

Facility and duration: LTRAC Water Facility Laboratory, Horizontal water tunnel. One student; ten weeks full-time under the ASPIRE Summer Research Program.

Project description

Flow separation over curved surfaces produces a region of reversed flow, increased losses and strong unsteadiness. The "NASA hump" is a standard geometry for studying this problem. At LTRAC, Jovic (2023, 2025) developed a NASA-hump model for water-tunnel experiments and used planar laser-induced fluorescence (PLIF) and four-camera particle image velocimetry (PIV) to resolve the separated and reattaching flow. Their work identified forcing frequencies that strongly manipulate the separated shear layer and showed that the reduction in reversed flow depends on both forcing frequency and perturbation strength.

This ASPIRE project will use the existing NASA hump model and optical arrangements in the LTRAC water tunnel. The student will investigate active control of the separated flow by using a high-speed laser to produce localised, periodic heating within a selected region upstream of, or within, the separation bubble. At one fixed tunnel speed, the student will systematically vary the laser forcing frequency and energy to establish a repeatable frequency–amplitude dataset and identify the actuation condition that produces the greatest measurable reduction in the size of the separation bubble.

Research question: How do the frequency and strength of periodic laser-induced thermal forcing affect the size of the separation bubble and the reattachment location over the NASA hump?

Experimental work

- Commission the existing experiment. Install the NASA-hump model in the LTRAC water tunnel, complete the required laser and water-tunnel training, configure the high-speed laser to generate localised periodic forcing in the selected flow region, and reproduce the established unforced reference flow.
- Conduct a bounded forcing study. Test a small, supervisor-selected matrix of forcing frequencies and strengths. Repeat all measurements at one fixed tunnel speed.
- Measure the separation response. Utilise particle imaging velocimetry (PIV) for efficient screening of the separation bubble and shear layer response. Apply PIV to the unforced reference case and selected effective forcing conditions, subject to scheduled facility access.
- Quantify the control effect. Determine the separation and reattachment locations, separation-bubble area, shear-layer motion and relevant velocity statistics. Assess measurement repeatability and uncertainty, and identify the forcing condition that produces the greatest reduction in the separation bubble.

Expected outcome and FYP continuation

Required continuation: Applicants must intend to continue this research into a Monash Engineering Final Year Project in 2027. The summer result will be a comprehensive experimental comparison at a single tunnel condition. The FYP will expand the frequency–amplitude map, examine Reynolds-number effects and use additional PIV/PLIF measurements to explain the controlling shear-layer dynamics.

Student background

Suitable for Mechanical or Aerospace Engineering students who have completed fluid mechanics and are interested in experimental work, flow visualisation, PIV/PLIF and MATLAB, Python or Julia analysis.

Research foundation

Jovic, D. (2025), An experimental investigation into forced separated-flow shear-layer instabilities and their effect on a separating–reattaching flow, Monash University PhD thesis. DOI

Jovic, D., Atkinson, C. & Soria, J. (2023), Large Field of View and High Spatial Resolution PIV of the Flow over the NASA Hump Model, ISPIV 2023. Source