MEng Project 7

Modeling SparkJet Actuation for High-Speed Flow Control

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Project objective and research question. This project will evaluate the plasma synthetic-jet actuator (PSJA), also called a SparkJet actuator, as a compact active-control device for high-speed flows. Unlike a diaphragm-driven synthetic jet, a SparkJet uses rapid electrical energy deposition to heat and pressurize a small cavity, producing a short, high-speed jet followed by slower replenishment. The research question is how actuator energy, repetition frequency, orifice geometry, orientation, and location influence jet impulse and the control of a canonical supersonic separated flow or shock-wave/boundary-layer interaction.

Engineering-science foundation. The work integrates compressible flow, unsteady mass and energy conservation, gas dynamics, shock waves, boundary-layer separation, pulsed jets in crossflow, vortex dynamics, thermodynamics, nondimensional scaling, and active-flow-control metrics. It also develops judgment about simplified plasma-energy-deposition models and their limits.

Methodology, data, and scope. The student will first reproduce a zero-dimensional or quasi-one-dimensional cavity model that converts a prescribed electrical-energy pulse into transient cavity pressure, temperature, exit velocity, and impulse. The model will be calibrated against published SparkJet measurements or simulations. Its output will then define a time-dependent boundary condition for a two-dimensional or reduced three-dimensional compressible CFD model of a supersonic crossflow, compression ramp, or separated shear layer. A designed study will vary velocity ratio, pulse timing, frequency, orientation, and actuator placement. Python will support analysis; COMSOL, OpenFOAM, SU2, or another approved compressible-flow solver may be used. The core project does not require high-voltage experiments.

Success metrics and contingency. Peak jet velocity and cavity pressure; impulse per pulse; jet penetration and circulation; separation-area reduction; shock-foot displacement or pressure-fluctuation reduction; control authority per deposited energy; and mesh/time-step independence. If coupled cavity/flow simulation is too costly, the fallback is a literature-calibrated pulsed-jet boundary condition and a reduced parameter study for one Mach number and one actuator location.

Two-Term Work Plan and Deliverables

Term	Planned productive work	Deliverable due by the last day of lectures
1	Literature review and application selection (22 h); implement cavity thermodynamic model (35 h); calibrate jet velocity and impulse against published data (28 h); establish baseline compressible-flow case (40 h); verification and documentation (15 h). Total: 140 h.	Interim report, calibrated actuator model, verified baseline flow case, and reproducible code/files.
2	Couple actuator output to compressible CFD (35 h); designed parameter study (45 h); quantify shock/separation control and energy cost (30 h); develop scaling or reduced-order design map (20 h); final report, repository, and presentation (20 h). Total: 150 h.	Validated SparkJet flow-control model, design map, complete computational package, and presentation.

Expected outcome. A computationally efficient framework for judging when SparkJet actuation can provide useful control authority in high-speed flows and which actuator parameters merit higher-fidelity study.