MEng Project 5

Thermal-Fluid Optimization of Miniature Synthetic Jets for Electronics Cooling

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Project objective and research question. This project will determine how a miniature synthetic-jet actuator should be sized, operated, and positioned to cool a localized electronic heat source. The research question is which combinations of resonant frequency, stroke length, jet-to-surface spacing, orifice geometry, and placement maximize heat-transfer enhancement per unit actuator power. The core work is computational, with optional limited bench validation if suitable hardware becomes available.

Engineering-science foundation. The project applies oscillatory flow, actuator resonance, vortex-ring formation, impinging jets, forced convection, boundary layers, conjugate heat transfer, dimensional analysis, and engineering optimization. It couples fluid dynamics with thermal design and performance constraints relevant to electronics.

Methodology, data, and scope. The student will first construct a reduced analytical model linking diaphragm motion, cavity response, and orifice velocity. A validated two-dimensional or axisymmetric unsteady CFD model will then predict jet formation and heat transfer from a heated surface. A designed parameter study will vary frequency ratio, stroke ratio, Reynolds number, spacing, and offset. Response-surface or Bayesian optimization will identify high-performing designs. The model will be checked against published correlations or available laboratory measurements. COMSOL, OpenFOAM, or another approved solver may be used with Python post-processing.

Success metrics and contingency. Time-averaged and peak Nusselt number; temperature uniformity; cooling per unit input power; pressure and velocity consistency; mesh/time-step independence; and agreement with reference correlations. If full conjugate simulations are too costly, the fallback is an isothermal-wall model with a carefully validated reduced design space.

Two-Term Work Plan and Deliverables

Term	Planned productive work	Deliverable due by the last day of lectures
1	Literature review and requirements (20 h); analytical actuator/jet model (30 h); establish and verify CFD model (50 h); mesh and time-step study (25 h); initial thermal results and documentation (15 h). Total: 140 h.	Interim report, verified baseline model, analytical scaling, and reproducible simulation case.
2	Designed parameter study (45 h); surrogate and design optimization (35 h); validate against correlations or available data (25 h); analyze practical design constraints (20 h); final report, files, and presentation (25 h). Total: 150 h.	Recommended design map, validated models and case files, final engineering report, and presentation.

Expected outcome. A defensible set of miniature synthetic-jet design and placement guidelines for localized electronics cooling.