



Ph.D. DISSERTATION DEFENSE

Candidate: Seyed Danial Ghasimi
Degree: Doctor of Philosophy
School/Department: Mechanical Engineering (ME) / Charles V. Schafer School of Engineering and Science (SES)
Date: Tuesday, March 31, 2026
Time/Location: 2:00 PM, Burchard 103
Title: Permeability Modeling of Mars Parachute Broadcloth Materials

Chairperson: Dr. Jason Rabinovitch, Department of Mechanical Engineering, SES

Committee Members: Dr. Nicholas Parziale, Department of Mechanical Engineering, SES
Dr. Kevin Connington, Department of Mechanical Engineering, SES
Dr. Dilhan Kalyon, Department of Chemical Engineering and Materials Science, SES

ABSTRACT

Every NASA mission that has landed on Mars has used a supersonic parachute to decelerate the spacecraft during descent. The broadcloth material used to construct parachute canopies is a thin, woven, permeable textile. The small length scales of the pores in the fabric cannot be resolved in full-scale parachute simulations, so reduced-order permeability models are used instead. In this work, incompressible Computational Fluid Dynamics (CFD) simulations through a simplified pore geometry are compared to experimental permeability test data to verify the geometric parameters used in these models. A series of CFD and Direct Simulation Monte Carlo (DSMC) simulations under high-altitude supersonic Earth flight test conditions is then performed to study fabric permeability in a low-density flow regime, where the mean free path of gas molecules is comparable to the pore size. The flow inside the pores is shown to resemble a developing pipe flow that does not reach a fully developed state, and a significant slip velocity is observed at the pore walls under low-density conditions. Pressure drag dominates the total drag on the material, and the previous analytical solution based on a simplified pore geometry solution predicts a higher total drag by only a small amount ($< 5\%$). To replace the trial-and-error approach previously used to identify simplified pore geometries that match experimental data, we present a surrogate-assisted multi-fidelity optimization framework for inferring simplified pore geometries of broadcloth parachute fabrics from standard permeability test data. The surrogate model combines physics-based trend functions for the Darcy-Forchheimer coefficients (k_1, k_2) with a Random Forest residual model trained on low-fidelity CFD data. A global multi-objective search is first performed with the surrogate model, and the selected simplified pore-geometry candidates are then refined using high-fidelity CFD simulations with a Powell optimization. The results are consistent with theory and demonstrate that permeability is most sensitive to the areal void fraction of an individual pore (referred to as porosity for simplicity). This multi-fidelity approach results in an efficient framework for deriving simplified pore geometries for parachute textiles from experimental data with minimal user input.