Design of a Novel Supersonic Nozzle Using a Multi-Objective Differential Evolution Framework

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The aerospace and launch vehicle industry has seen a resurgence in growth and commercialization in recent years. Companies have always strived to improve their rocket propulsion systems to both lower costs and increase payload capabilities, whether that be through innovative propellant combinations or new plumbing cycles. However, one critical factor of all rocket engines—the over 130-year-old de Laval nozzle—has hardly changed since its inception. This project aims to reinvent the rocket nozzle using modern search techniques to explore the near infinite geometric search space for a new, optimal geometry. Differential Evolution (DE) was the chosen optimization technique due to two main motives: DE does not require a differentiable cost function and is easily implementable for multi-objective purposes. DE was also compared to machine learning techniques. My approach was to generate an initially large and diverse population of nozzle geometries and iterate through a specified number of generations using a rudimentary cost function. This cost function is multi-objective and accounts for factors such as the final exhaust velocity, shock dissipation, heat flux, and.engine inert mass. Thermodynamic parameters were calculated through isentropic flow and shock/expansion fan propagation once the flow becomes supersonic. After a certain threshold is reached, the remaining generations of geometries are evolved with an automated version of the popular CFD program, ANSYS Fluent, as the cost function. A machine learning model was also considered and tested to approximate the CFD analysis as the computational requirements of full CFD analyses are costly.