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MULTI-POINT FOREBODY SHAPE OPTIMIZATION FOR REUSABLE LAUNCH SYSTEM USING ROCKET AND SCRAMJET PROPULSION

Abstract

Scramjet propulsion is a promising airbreathing technology for achieving economical and reliable hypersonic atmospheric transportation. A reusable launch system (RLS) powered by rocket and scramjet engines is being considered to address the drawback that scramjets cannot operate below hypersonic speed or in low air density at high altitude in a complementary manner. Research efforts have predominantly been devoted to components of direct relevance to the propulsive performance of scramjet engines such as the air intake, combustor, and nozzle.

Other aspects such as the configuration and trajectory, however, are also integral to the RLS and thus requires careful attention in the system development. In particular, the vehicle forebody comprising the nose cone must be designed in a cohesive manner such that it incurs minimum drag and maintains an acceptable level of aerothermal heating, while producing desired airflow that enters the scramjet engine as the forebody shape crucially determines the inflow for the scramjet intake located downstream. However, literature on the influence of the forebody shape on the flowfield relative to the intake is rather sparse or none in the public domain.

To fill this gap in knowledge, the present study is conducted using multi-objective design optimization (MDO) in four phases to; (1) determine suitable parametrization for the forebody via MDO employing modified Newtonian theory; (2) scrutinize the influence of the forebody shape on aerodynamic drag and inflow for the scramjet intake via multi-point MDO based on surrogate-assisted evolutionary algorithms, aiming to simultaneously optimize 4 objective functions, i.e., minimum total drag and maximum inflow uniformity for the intake at multiple operating conditions, while satisfying the aerothermal constraints; (3) investigate the influence of the inflow uniformity on the performance of the scramjet engine; and (4) evaluate the overall benefits in terms of space transportation performance via trajectory optimization, accounting for the changes in aerodynamic characteristics and propulsive performance as a result of the former MDO phases.

The influence of decision variables on the performance of the vehicle system is investigated by means of variance-based sensitivity analysis to identify influential design factors and their interactions for physical characterization. The flowfields are scrutinized for representative cases to gain insights into underlying flow physics and aerodynamic phenomena such as shock waves, boundary layers, and their effects on the

performance. The new knowledge will conduce to robust, efficient design and operation of RLS using rocket and hypersonic airbreathing engines.