Aerospace Europe Conference 2023
Joint 10th EUCASS – 9th CEAS Conference

Abstract #XXX
Preferred Topics: SYSINT/ STUDENT
Corresponding author: Mitchell Galletly
e-mail of corresponding author: mitchell.galletly@sydney.edu.au
Type: Oral
Status of corresponding author: Student

Title

Design Optimisation of Hybrid Propellant Launch Vehicles

Authors

Allen Chan [1], Mitchell Galletly [2] *, Dries Verstraete [3]*

** Corresponding author*
[1] University of Sydney, Sydney, Australia, acha7851@uni.sydney.edu.au
[2] University of Sydney, Sydney, Australia, mitchell.galletly@sydney.edu.au
[3] University of Sydney, Sydney, Australia, dries.verstraete@sydney.edu.au

Abstract

Hybrid propellant rockets engines offer a range of operational advantages over current propulsion systems due to their inherent safety and reduced design complexity. Historically, the maturation of this class of engines has not been actively pursued to the degree of liquid bi-propellant rocket engines and solid rocket motors due to underlying performance limitations. This is a result of the poorer combustion efficiencies and reduced fuel regression rates inherent to the engine. However, recent developments have seen hybrid propulsion systems become increasingly practical, with significant investment in this technology made by major aerospace research institutions and startup companies.
In light of these recent endeavours, this paper presents a vehicle design optimisation framework to facilitate the development of hybrid propellant launch vehicles. Vehicle design and sizing is a cyclic and iterative process, requiring complex trade-offs between individual subsystems and the mission objectives. This work proposes a launch vehicle modelling and simulation tool interfaced with an optimisation suite to automate the design process at a preliminary design stage. The software implements a medium-fidelity numerical model to simulate the oxidiser tank dynamics, chamber internal ballistics and nozzle flow for accurate predictions of the overall engine performance. This module is interfaced with NASA-CEA for chemical equilibrium calculations. Weight estimation and aerodynamic prediction is conducted using a component build-up approach for higher levels of accuracy. Finally, the flight profile is modelled using a 6 Degree of Freedom (6-DOF) trajectory simulator. Comparison of the modelling tool with experimental data found in literature showed good agreement with margins of error within 15 %, in line with preliminary design accuracies found elsewhere.
Multidisciplinary design optimisation is performed using a Non-Dominated Sorting Genetic Algorithm (NSGA-II) to determine the ideal vehicle design for a range of mission profiles. The conceptual design of a 30,000 ft vehicle for Spaceport America Cup and a 100 km experimental sounding rocket is developed using this framework (see figure). A detailed analysis of the derived vehicle designs is examined to assess the effectiveness of the design tool. The optimiser produced vehicles very similar in size to existing flight proven vehicles confirming that the results are credible. The study also demonstrated the effect that the choice of propellant and fuel grain geometry had on the overall vehicle design.

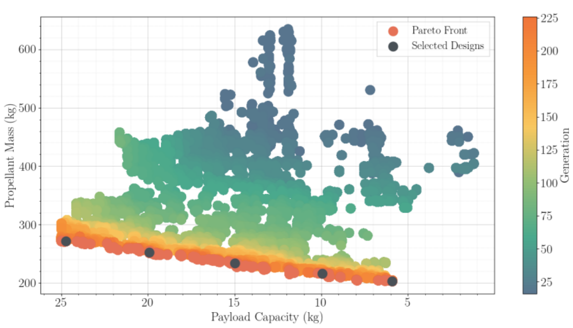

Figure 5.18: Pareto front for payload to propellant mass minimisation case using HTPB (circular port geometry).

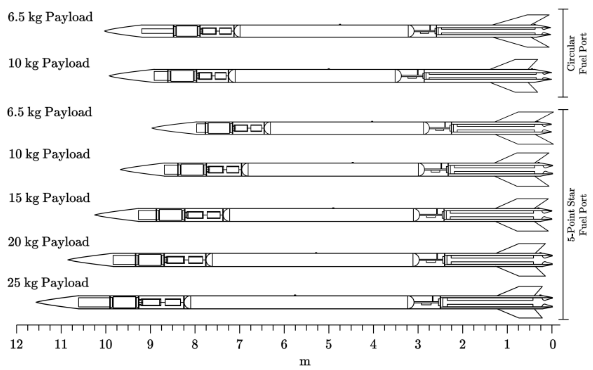

Figure 5.19: Comparison of vehicle schematics.