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OPTIMIZATION STUDY OF AN UPPER STAGE BASED ON AN E-PUMP-FED ENGINE

Abstract

The growing demand for increasingly high-performance propulsion systems has led to the need for engines with high value of combustion chamber pressure. In 2017, Rocket Lab demonstrated the feasibility of using an e-pump-fed engine for both the first and upper stage of its Electron launcher. This type of architecture demands a complex engineering effort, which involves the use of precise tools to refine the choices made during the preliminary design phase. For this reason, this research aims to present a design tool for optimizing a LRE upper-stage fed by an e-pump cycle. To improve the accuracy of the results, the algorithm combines engine sizing with the optimization of the inboard profile of the stage. Specifically, it designs the shape and arrangement of the tanks according to the available envelope inside the stage. Then the optimizer exploits the model to minimize an objective function defined by the dry and propellant masses, weighted by tuning coefficients related to the adopted engine cycle. A validation analysis highlights the capability of the algorithm to optimize accurately the design. The second stage of the Electron rocket has been investigated, reaching a maximum error of 9.6% on the design variables and a discrepancy lower than 1% for the stage masses estimation. A sensitivity analysis is conducted to study the influence of the design parameters of an e-pump engine (like battery, motors and inverter efficiency and specific density) on the overall stage optimization.

Finally, the tool is employed to investigate alternative configurations for the Ariane 5G+ second stage (AESTUS engine). As an example, using an e-pump cycle with $N_2O_4 - CH_6N_2$ results in an optimized design with a payload mass improvement of about 12%. Considering the recent trend of the space sector to move toward the use of green propulsion, new optimal designs are found assuming the AESTUS's performance and geometric constraints and adopting green propellants and different cycles for the propulsion.