Abstract

Hybrid rocket engines are a promising propulsion system, albeit being not as well developed as other chemical rocket systems at the date. Wide thrust range and fine control features (including shut-down and re-ignition capabilities) make the hybrids suitable for many applications, including small launchers, space propulsion systems and upper stages, which have been considered in the present work as test case.

Hybrid rocket engines are safer than solid rocket motors and cheaper than liquid rocket engines, having, at the same time, a low environmental impact. In general, a hybrid powered stage can easily be employed in place of conventional solutions, granting larger payload mass and lower overall cost. On the other hand, the actual use of hybrid propulsion systems is still limited by a number of issues, including low regression rates, combustion instability and intrinsic uncertainty in the hybrid combustion process.

The author developed a robust-based optimization procedure, which consists of a sensitivity analysis method, used to identify the most relevant source of uncertainty in the numerical model, and several design of experiments techniques, employed to evaluate system performance in the presence of uncertainty and grant robustness in the design. The optimization of a hybrid powered upper stage, suitable as a replacement for the actual Vega launcher upper stages, was considered as a test case. Different feed systems were also taken into account and compared.

Results showed that robustness in the design is achievable, despite the presence of uncertainty, when the proposed procedure is employed for the optimization of the hybrid rocket engine, also granting a relevant payload gain with respect to the current launcher configuration.