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ROBUST DESIGN OPTIMIZATION OF A LAUNCH VEHICLE IN PRESENCE OF PARAMETRIC UNCERTAINTIES

Abstract

All through the lifecycle in a realistic world, there inherently exists a vast quantity of uncertainties arising from the aerospace vehicle system itself, as well as the environmental and operational conditions it is involved in. The more advanced and accurate analytical approaches are developed to consider uncertainties which, based on them, two categories of uncertainty-based design methods, namely robust design optimization and reliability-based design optimization exist. The aerospace vehicle disciplines are naturally close coupled and uncertainty impacts are cross propagated, it is much more desirable to take a holistic approach to solve the multidisciplinary design optimization (MDO) problem so as to enhance the system design by exploiting potential synergistic effect of the coupled disciplines. From this perspective, Uncertainty-Based Multidisciplinary Design Optimization (UMDO) is introduced into academia. In this work the robust design optimization of a two stage expendable Launch Vehicle considering parametric uncertainties is presented. One method for achieving robustness is to minimize both the mean and variance. Thus, the problem is viewed as a multi-objective constraint optimization formulation. Propulsion, Aerodynamic, and Trajectory are the considered disciplines in this design problem. A Three-degree-of-freedom trajectory program using proper and accurate atmosphere and earth models is simulated. Uncertainty in some design parameters that have more effects on the design and objective function, such as those in vehicle dry mass, engine's thrust, aerodynamic coefficients and engine's burn time, are considered with the aim of probability analysis and normal distribution. Monte Carlo Simulation (MCS) is used for uncertainty propagation and analysis in which mission constraints (such as orbital height, orbital velocity and trajectory angle at the end of flight) are considered as output parameters. The objective function is to minimize the vehicle total mass subject to mission and trajectory constraints while being robust under applied uncertainties. In order to achieve this goal, the second stage trajectory design is considered and, for the first stage flight, an optimal trajectory is utilized. The optimal and the robust solution are also compared. The results illustrate that although the robust trajectory will be a little far from optimal design but it's less sensitive to uncertainties.