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MULTI-ATTRIBUTE EVALUATION APPROACH FOR SMALL LAUNCH VEHICLE WITH MULTI-OBJECTIVE MULTI-DISCIPLINE DESIGN OPTIMIZATION

Abstract

In the traditional flight vehicle design, technical performances of aerospace vehicles (e.g. the take-off mass and the payload ratio) have been concerned by the designers for a long time. However, with the increasing emphasis on the comprehensive properties of the aerospace vehicles, non-technical attributes (e.g. economy, operability, safety and environmental protection) have been taken into account by launch vehicle designers. In this paper, a novel synthetical multi-attribute evaluation approach for small launch vehicles (SLVs) is proposed. In addition to traditional technical performances, other attributes, including cost, operability, manufacturability, flexibility, and safety/environmental-friendly characteristics, are considered for comparison. Three chemical propulsion systems, which are solid rocket motor (SRM), liquid rocket engine (LRE), and hybrid rocket motor (HRM), are adopted for the design optimization of a small launch vehicle and comparison of the multi-attribute evaluations. Four disciplines are considered to establish the system design model of the small launch vehicle, including the propulsion, the structure, the aerodynamics, and the trajectory. The Ziolkovsky formula is used to estimate the total velocity increment needed for the orbit condition. Cost models for different propulsion are established respectively. And two performance parameters, the taking-off mass and total cost of the launch vehicle, are selected as the design targets of the multi-objective optimization, which aims at the same design reference mission, 100kg payload injection at 300km circle low earth orbit. Moreover, fuzzy decision method is adopted to quantitatively characterize expert evaluation in the multi-attribute evaluation (MAE). In order to synthesizely evaluate the suitability of each propulsion system, TOPSIS multi-standard decision scheme is implemented based on entropy weight method. The results show that all MDO models acquire a series of solutions with two objectives (takeoff mass and total cost) for SLV. Aiming at the same index, SLV powered by SRM has the smallest takeoff mass, while SLV powered by HRM emerges the lowest cost. Pareto front indicates that positive correlation exists between total cost and takeoff mass at the range of whole design space. The proposed synthetical MAE approach is proved to be flexible for SLV design, and can be extended to other attributes. HRM is proved to have the most competitive advantages for small payload injection.