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Author: Dr. Chunlin Gong
Northwestern Polytechnical University, China, leonwood_0@hotmail.com

Prof. liangxian gu
Northwestern Polytechnical University, China, gulx@nwpu.edu.cn
Mr. Hua Su
Northwestern Polytechnical University, China, Suhua@nwpu.edu.cn

HIGH-FIDELITY MODEL BASED MULTI-DISCIPLINARY OPTIMIZATION FOR SUBORBITAL REUSABLE LAUNCH VEHICLE

Abstract

Suborbital Reusable Launch Vehicle (SRLV) suffers less severe flight environment, and is more realistic for near future launch vehicle development. However, SRLV also need to experience wide velocity regions. The interactions between aerodynamics, structure, thermal, trajectory, etc. are very tightly just like RLV. Therefore, it is unavoidable to utilize Multidisciplinary Optimization (MDO) technology in the design process. For the purpose of exploring multidisciplinary coupling influences more precisely, this research focus on high-fidelity model based MDO. A SRLV concept serving as booster of orbital vehicle was selected as baseline. The design system was decomposed into seven disciplinary component of geometry, aerodynamics, propulsion, flight trajectory, aero-heating/TPS sizing, structure, Stablity Control. The functions of disciplines and dataflows between them were defined. Since the fidelity level of MDO model has significant effects on optimal, several fidelity aspects not only disciplinary analysis, but also coupling between them, were considered, including: 1.CFD method was used in aerodynamic performance analysis, and the influence of airframe flexibility was considered by coupling CFD and structural FEM. 2.CFD (Euler equations) was used to calculate boundary flow parameters of pressure, velocity, density, etc., and as input of aero-heating calculation. Also, the finite differentiation method was used for heat transfer analysis and TPS sizing. 3.In structural stress analysis, FEM was used. Moreover, considering that airframe endures high temperature and heat flux when reentry, thermal flux and temperature were added as structure load. 4.Traditionally, we avoid flutter by give some limitation in flight velocity and dynamic pressure. In this research, the flutter influence was simulated more accurately by unsteady CFD and FEM coupled, and the results were feedback to limitation flight path. After the disciplinary analysis model being built, the optimization problem of objective, constraints and variables was defined. Within multidisciplinary framework software, the architecture of Multi-Disciplinary Feasible (MDF) was applied to integrating disciplines.Genetic Algorithm was chosen to optimize take-off weight of SRLV. The results show that mass of structure and TPS parts increases by slightness, but the fuel mass decreases about 8.2 percent, and as a whole, the take-off weight was improved about 4.6 percent.