SPACE PROPULSION SYMPOSIUM (C4)
Hypersonic and Combined Cycle Propulsion (5)

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# MULTIDISCIPLINARY DESIGN & OPTIMIZATION MODELS AND SOFTWARE TOOL FOR HYPERSONIC FLIGHT VEHICLE

**Abstract**

The interdisciplinary tight-coupled aspect of air-breathing Hypersonic Flight Vehicle (HFV) necessitates truly Multidisciplinary Design and Optimization (MDO). In this research, several critical disciplines of HFV were considered, such as Geometry, Aerodynamics, Propulsion, Trajectory/Control, Structure, Thermal Protection System (TPS), and Radar Cross Section (RCS). From the viewpoint of system engineering, we created the MDO models of HFV. By introducing the conceptions of "shared variable", "transition constraint" and "transition objective", the system optimization problem of HFV was formulated based on the design description of each discipline. Six disciplinary analysis models of middle fidelity were constructed, including: 1.An inexpensive Variable Complex Model (VCM) with Newtonian model and CFD model integrated to estimate aerodynamic performance. 2.Quasi-one-dimensional model with finite-rate chemistry to predict performance of Scramjet. 3.A 3-D trajectory to calculate flight performance with altitude and fuel control schemes considered. 4.Finite Element Model (FEM) to estimate structural performance metrics of stress, deformation and natural frequencies. 5.Reference enthalpy model to calculate aerodynamic heating environment, and FEM to simulate thermal transfer process through TPS and wall. 6.High frequency Physical Optics (PO) method to compute RCS of vehicle shape. Additionally, a master geometry model was built to control geometric parameters of each discipline. Encompassing interdisciplinary interactions, a Design Structure Matrix (DSM) was created as multidisciplinary analysis model. To support MDO process of HFV, we developed a CAD-based software tool named MDOT-HFV. MDOT-HFV is composed of five ingredients: (a) Parametric Geometry Modeling (PGM) module, based on CATIA and CAA interface; (b) Disciplinary analysis codes, corresponding to aforementioned disciplinary models; (c) Integration Core (IC) and Data Base Management System (DBMS) module, which controls interaction between analysis codes and CATIA; (d) Graphical User Interfaces (GUI); (e) Optimization tools with several algorithms supplied. MDOT-HFV has two kinds of operation mode, collaborative and automatic execution. Disciplinary designer deal with their subsystems separately, and publish subsystem models. System designer assembles these sub-models into an integrated MDO model. Defining objectives, variables and constraints, system designer can optimize the vehicle parameters automatically. MDOT-HFV was developed for conceptual design of Scramjet Cruise Vehicle (SCV), but not limited to. For the purpose to describe MDOT-HFV in detail, one design example was introduced.