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SIMULATION-BASED MULTIDISCIPLINARY DESIGN OPTIMIZATION OF THE OXIDIZER PUMP IN THE TURBOPUMP SYSTEM

Abstract

The reduction in weight of the propellant pumps in the turbopump system will contribute largely to the reduction of the spacecraft payload. This paper presents a simulation-based Multidisciplinary Design Optimization (MDO) procedure to minimize the overall weight of the oxidizer pump. Specially, a parametric model of the oxidizer pump in the geared liquid-bipropellant turbopump system developed for the 188,000-1b-thrust LOX/RP-1 booster engine is built to provide a variable geometry for the whole analysis. Simulations involving structural, fluid dynamics and thermal dynamics analysis for three discipline-level performances optimization are performed on the CAD/CAE platform simultaneously and respectively. A synthesized automatic solving system is constructed on the optimization platform which integrates the CAD/CAE software for the numerical simulation, multiple optimization algorithms for the system-discipline level coordination, design of experiment techniques for the sampling points generation, and approximation models for the system-discipline data exchange. The key issue involved in this optimization process is the foundation of MDO-oriented mathematical models corresponding to a combination of the design variables (geometric structure, flow velocity etc.), state variables (pressure head, flow rate etc.) and the constraint conditions etc. In particular, results comparison and theoretical analysis are made to provide guidance for choosing appropriate approximation models including the polynomial response surface method, the Kriging method and the radial basis function method in the oxidizer pump weight optimization process. The simulation-based MDO procedure above presents the methodology of designing turbopump system components in the Liquid-propellant Rocket Engine with a high efficiency and low cost.

Keywords: Oxidizer pump, Multidisciplinary design optimization, Integrated optimization platform, Numerical simulation