# Multi-disciplinary Design Optimization of Hypersonic Vehicles with the Generalized Sensitivity Based Concurrent Subspace Optimization Process

Li Yan, Wei Huang, Jie Li, Xiao-qian Chen
*Science and Technology on Scramjet Laboratory, National University of Defense Technology, Changsha, Hunan, 410073, China*

The systemic design of flight vehicles involves many interactions between different disciplines, and the computational and communicational complexity makes the overall design process extremely complex. In order to obtain the highest potential benefit of integrated design and improve the design quality, the multi-disciplinary design optimization (MDO) method has attracted an increasing attention. The valid design/analysis/optimization processes have been employed in the MDO method to integrate the knowledge of various disciplines, and the organization and management has been carried out in the design process of the whole system. Then, the overall optimal solution of the system can be obtained by exploiting the synergism of interacting phenomena.

In the current study, four key technologies of the MDO approach have been studied firstly, namely the sensitivity analysis, the approximation strategy, the search strategy and the optimization process. In order to solve the sensitivity analysis problem of discrete variables, the generalized sensitivity concept has been presented, and it is suitable for the continual/discrete variables. Then, the generalized sensitivity method has been applied to the approximation strategy and the search strategy subsequently. The Concurrent Subspace Optimization (CSSO) process has been studied as well. The advantages and disadvantages of the standard CSSO process, the improved CSSO process and the response surface based CSSO process have been systematically analyzed, and some improvement steps have been proposed. Additionally, the move limit strategy has been discussed during the investigation of the CSSO process, and finally, a new optimization method has been proposed, namely the Generalized Sensitivity Based Concurrent Subspace Optimization (GSBCSO) approach. Compared with the existing CSSO process, the GSBCSO process owns many advantages, i.e. broader applicability and cheaper cost for computation.

At last, the GSBCSO process has been applied successfully to the overall design of a hypersonic vehicle which has the strongest interactions between disciplines, and it is suitable for the optimization and solution of the systemic performance of the hypersonic vehicle. Fig. 1 shows the optimization flowchart of the baseline scheme for the hypersonic vehicle based on the GSBCSO process. The obtained results indicate that the GSBCSO process reduces the iteration numbers for the systemic analysis, and the computational complexity decreases as well. The systemic performance of the hypersonic vehicle has been improved to a certain degree when compared with that obtained by the Multidisciplinary Discipline Feasible (MDF) process, and this lays the foundation for the overall design of hypersonic vehicles.

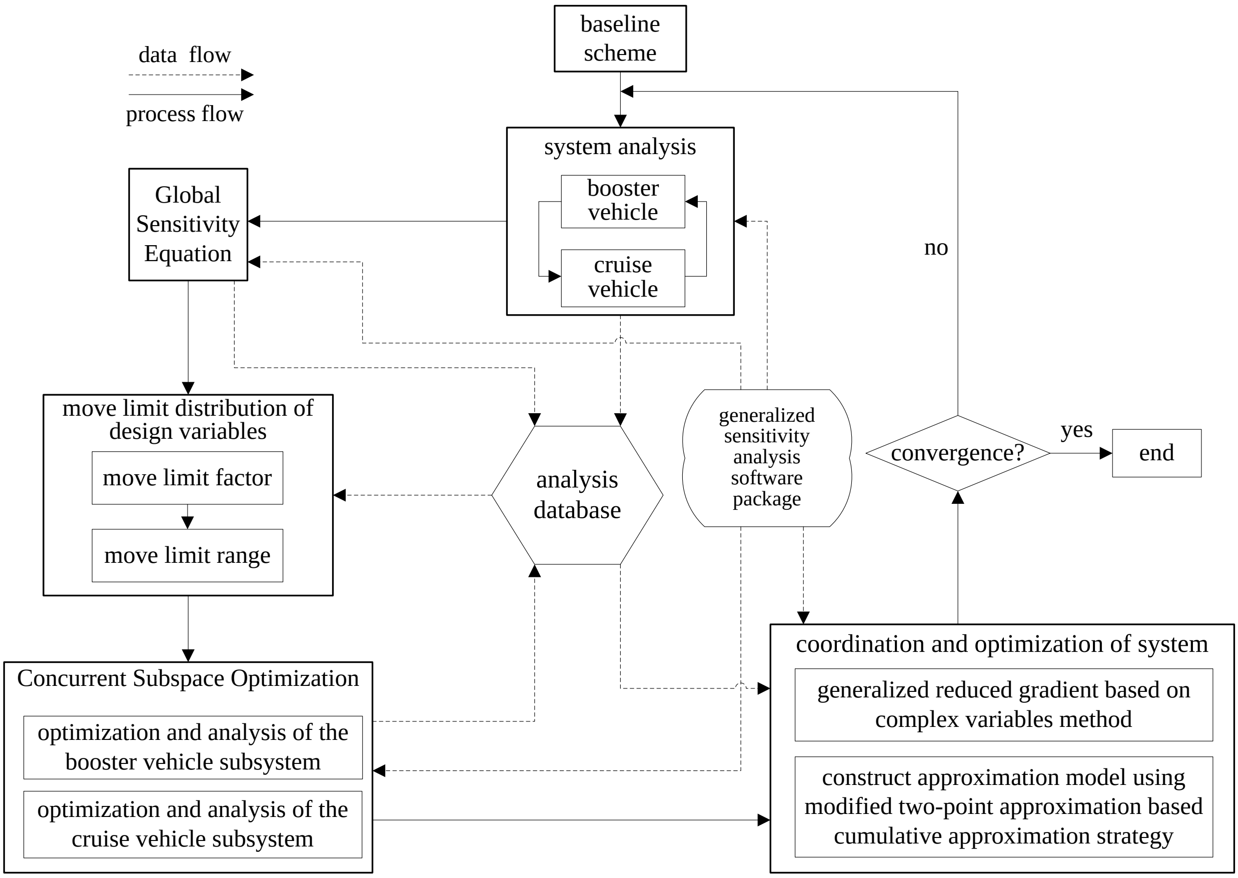


Fig. 1 The Optimization Flowchart of the Baseline Scheme for the Hypersonic Vehicle Based on the GSBCSO Process