Title:

Design Exploration of Robust Topologies under the Loading Uncertainty for the Lug Structure of Super Sonic Transportation

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Abstract:

In Super Sonic Transport (SST), thin wing structure is necessary to satisfy the high speed, economic viability and environmental compatibility requirements. Among many structures in thin wing, the lug structure which is between the body and the main wing plays important role. However, it is difficult to design of the lug structure because it is subjected many loads that have uncertainties such as magnitude or direction of loading caused by aeroelastic forces. Robust topology optimization is, therefore, necessary to determine the optimal structural lay out solutions insensitive to loading uncertainties for design of the lug structure.

For robust topology optimization with uncertainty in loading, there are several methods have been developed. The most famous approach is the one based on the minimum variance-expected compliance model with multiload formulation. This model can evaluate the robust structure performance using variance-expected compliance against the uncertainty. In this model, sensitivity analysis is commonly used for the efficient optimization. Although it is computationally effective, sensitivity analysis cannot perform a global search. Moreover, it is not clear that how to determine the weighting factor which is used to transforms a variance and an expected compliance objectives into one objective.

In this study, we propose new alternative approach using NSGA-IIa (Archiving elitist non-dominated sorting genetic algorithm) for minimum variance-expected compliance model. NSGA-IIa is one of the most popular methods in Multi-Objective Evolutionary Algorithms (MOEA) for multi-objective optimization. The main advantages of proposed method are that MOEA is not necessary the weighting factor in the objective function and can be obtained Pareto-optima solution which represents a different compromise solution between robust design objectives. After that the proposed approach was applied to robust topology optimization of the lug structure of SST with loading uncertainty.

In the present study, there are 3 stages in the proposed approach for design exploration of robust topology. First stage is to find Pareto-optima solutions in compliance objective space of each loadcase by using NSGA-IIa. For the efficient topology optimization using GA, Bar-system representation method that based on graph theory is used. In this stage, objective function is compliance which is commonly used topology optimization field, so that is easy to implementation. Thus there is no necessary to formulate directly both variance-expected compliances which are complicated. In second stage of this approach, for calculation of the variance-expected compliance Monte Carlo simulation was used to evaluate the robustness of Pareto-optima solutions obtained first stage. Through this stage, we are able to obtain quasi-Pareto solutions of the variance-expected compliance space. After that, Self-Organizing Map (SOM) that is an appropriate tool to visualize and explore properties of the high dimension data, are applied to

investigate the relationship between robust topologies and design space at third stage.

Finally, proposed approach was applied to the lug structure of SST for robust topology optimization. Topology of the lug structure, which is subjected to bending moment and shear force with loading uncertainty, was optimized to minimize variance-expected compliance with a volume constraint and quasi Pareto-optima solutions of robust topology were obtained.

Key words: Structural Optimization, Lug Structure of Super Sonic Transportation, Robust Topology Optimization, Multi-Objective Optimization, Multi-Objective Genetic Algorithm, Design Exploration.