Reliability-Based Robust Design Optimization Using a Probabilistic Robustness Index and the Conjugate Gradient Method

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Optimization considering the uncertainty can be classified into robust design optimization (RDO) and reliability-based design optimization (RBDO). RDO pursues an insensitive and conservative design when there are variations on design variables and parameters. In RDO, various robustness indices for the objective function and constraints have been developed. RBDO has been studied to consider the uncertainty effect in the constraints. Therefore, RBDO provides a safer and conservative design compared to deterministic design optimization because it considers the uncertainty based on the probabilistic theory. Various researches have been performed to develop the reliability assessment and RBDO. However, the RBDO application to practical engineering structures is still a challenge because of the high computing cost.

In this research, a new robustness index for RDO is proposed based on the probabilistic theory. An investigation is performed to identify the characteristics and the drawbacks of the previous studies, and useful information about the probabilistic robustness index is described. Also, this research presents a new reliability-based design optimization method to improve the efficiency and convergence capability. An effective method for RBDO is proposed enhancing the single loop single vector (SLSV) approach by the conjugate gradient method. It is well known that the SLSV method improves the computational efficiency of RBDO by eliminating the reliability analysis process. However, this method has a weakness in that instability or inaccuracy can be increased according to the problem characteristics. The SLSV method is modified by using the conjugate gradient to overcome such weakness.

Finally, reliability-based robust design optimization (RBRDO) is implemented in this study. The RBRDO is an integrated method that accounts for the design robustness in the objective function and for the reliability in

the constraints. The objective function in RBRDO is expressed by the probabilistic robustness index. The SLSV approach using the conjugate gradient method is applied to realize the feasibility of the constraints in the RBRDO process. Consequently, the proposed RBRDO technique seeks the best compromise between an insensitive and a reliable design.

The proposed RBRDO method is applied to numerical examples and structural applications. The results are compared to the previous methods. It shows that the proposed method is accurate and more efficient than the other methods. Also, the results reveal that the proposed method can be successfully applied to practical structural problems.