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An efficient single-loop strategy for reliability-based multidisciplinary design optimization under non-probabilistic set theory

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Abstract: Non-probabilistic reliability based multidisciplinary design optimization (NRBMDO) offers a powerful tool for making reliable decisions with the consideration of uncertain-but-bounded uncertainties for complex engineering systems. However, the prohibitive computation and convergence difficulties caused by the directly coupling of uncertainty based multidisciplinary analysis (UMDA), non-probabilistic reliability analysis (NRA) and MDO would seriously hamper the application of NRBMDO. In this paper, an efficient single loop strategy for NRBMDO (SLS_NRBMDO) is developed to decouple the nested issue and thus improve the computational efficiency. The key idea of the proposed strategy is decoupling NRBMDO with several cycles of sequential MDO, UMDA, NRA and translating distance calculation (TDC). For UMDA, three methods, i.e., the first order interval Taylor expansion method, the interval vertex theorem, the direct optimization approach are formulated. Besides, NRA is conducted on the basis of the expanded non-probabilistic stress–strength interference model and the volume ratio thought, which provides a clear and definite assessment criterion for the structural safety with uncertain-but-bounded parameters. Furthermore, the translating strategy based on the performance measure approach is proposed to shift and update the constraints, and the expression of the translating distance is mathematically derived to accelerate the design procedure. Eventually, the effectiveness and efficiency of the proposed method are illustrated with one numerical case and one practical supersonic wing optimization design problem.

Keywords: Non-probabilistic reliability based multidisciplinary design optimization; Single loop strategy; Uncertainty multidisciplinary analysis; Non-probabilistic reliability analysis; Translating distance calculation.

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