Worst-case design of plane frames using order statistics

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Optimization of plane trusses and frames under uncertainty has attracted wide attention during the past few decades. Generally, these optimization methods can be classified into two categories according to the models for characterizing uncertainty [1, 2]. When a probabilistic model is used, uncertainty is assumed to obey some predefined distribution, and the objective and constraint functions are usually formulated as functions of statistical moments or probability of failure corresponding to the structural response, which can be referred as reliability-based structural optimization (RBSO) or robust structural optimization (RSO). However, since the exact distribution information of uncertainty may be unknown beforehand, a large estimation error would occur in both RBSO and RSO when the assumed distribution of uncertainty is far away from the real one.

On the other hand, the worst-case optimization (WCO) provides an alternative if uncertainty is described by a non-probabilistic model, which often aims at minimizing the structural cost under constraints on the maximum response within the predefined set of uncertain parameters. In order to save computational costs for searching the worst value, the authors recently proposed an order statistics approach for multiobjective structural optimization under uncertainty [3], in which the exact worst value is relaxed to a quantile response and the robustness level of the approximate worst response value is defined by the order statistics based on the theory of distribution-free tolerance interval. It has been shown that the solutions with different robustness levels at the same confidence can be simultaneously obtained, and the values of optimal design variables depend on the level of robustness.

In this study a worst-case design of shape and topology optimization of plane frames considering global stability is presented. Each member of the frame structure is assumed to have a solid circular cross section. A method is presented for modeling the correlated imperfections along with each member, and a penalization approach is proposed for excluding superficial local buckling. The order statistic corresponding to the specific robustness level is used for the objective function and the global stability constraint. To alleviate the difficulty caused by melting nodes in shape optimization to some extent, the shape of the frame structure is determined by the force density method which is applied to the auxiliary truss structure that is irrelevant to the true loading and boundary conditions of the frame structure to be optimized [4]; thus the design variables are the force densities of the auxiliary pin-jointed structure and the cross-sectional areas of the frame. The performance and properties of robust shape and topology are investigated in comparison to those without considering uncertainty.

Reference

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