Design optimization of structures under buckling constraints considering imprecise material and loading

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Abstract

Design optimization can lead to structures, which are susceptible to even small uncertainties especially in terms of stability. Stability against buckling is a response, which is critical to structural integrity. The consideration of uncertainty is vital to understanding the behavior of the real structure as uncertainties are unavoidable. In this study fuzzy models for imprecise material and loading are used. The fuzzy responses are then used in structural optimization.

Engineering information is often uncertain, vague, deviated, imperfect, erroneous, imprecise, etc. Uncertainty can be categorized in two general types: aleatoric uncertainty due to randomness and epistemic uncertainty due to lack of information or imprecision. This study will deal exclusively with the latter, where standard methods using probability have shown limitations. Fuzzy methods, based on possibility theory outlined by Zadeh (7), Dubois & Prade (2), etc., are well suited for describing epistemic uncertainty. Included in epistemic uncertainty are data sets where only few samples are available and are appropriately modeled with fuzzy methods. The resulting fuzzy parameters can then be used in structural analysis, allowing for nondeterministic consideration and, therefore, uncertainty assessment. Möller (6), Hanss (4), Choi (1), Farkas (3), Huber (5), among others have used fuzzy techniques in mechanical and civil engineering applications to deal with uncertain and imprecise parameters. A challenge remains the computational effort of the integration of nonlinear analysis of uncertain systems in design optimization. As nonlinear and linear structural analysis of stability is sensitive to uncertainties and imprecision, it is important to consider possible deviations to the idealized model, in order to get a optimal design that is robust against such uncertainties.

Fuzzy analysis in the framework of structural design optimization is carried out using linear as well as nonlinear buckling analysis of frame structures as constraints. Material and, especially, loading represent the main sources of imprecision in mechanical analysis. Two structures are used in this study: simple two beam frame structure and a complex engineering example, a vehicular space frame. A comparison is made between the optimization of the deterministic and nondeterministic systems analyzing the information gained through the consideration of uncertainty.

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