11th World Congress on Structural and Multidisciplinary Optimisation
07th -12th, June 2015, Sydney Australia

Interval buckling analysis of steel structures using mathematical programming approach

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Abstract

A novel mathematical programming approach is proposed in this study to assess the linear buckling load of steel structure with uncertain system parameters. The considered uncertainties of system parameters are modelled by the interval approach such that only bounds of uncertain parameters are available. This particular uncertainty model is applicable for situations where probabilistic approach is inapplicable due to the insufficiency of the data of system parameters. By implementing an alternative finite element formulation for the two-dimensional beam element, the deterministic second order geometrically nonlinear problem is formulated into a mathematical programming problem. Furthermore, by treating all the interval uncertain system parameters as bounded mathematical programming variables, the integration of interval uncertainties in the deterministic linear buckling analysis becomes possible, such that the lower and upper bounds of the buckling load can be adequately obtained by solving two explicit nonlinear programs. The proposed computational scheme offers a single-phase interval buckling analysis for steel structures by combining the linear analysis of the structure at its reference configuration with the eigenvalue calculation. Such ability can well maintain the physical feasibility of the engineering structures for the purpose of uncertainty analysis, so the physically meaningful lower and upper bounds of the buckling load can be efficiently obtained. In addition, unlike traditional uncertain buckling analysis, the proposed method is able to thoroughly model the dependency between uncertain system parameters (i.e., the physical relationship between cross-sectional area and second moment of area of beam element must be compatible when cross-sectional area possesses uncertainty). One numerical example is presented to illustrate the accuracy and applicability of the proposed approach.

Keywords: interval analysis; buckling; steel structure; mathematical programming; dependency.