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Topology Optimization of Continuum Structures Considering Compliance, Stress and Buckling Constraints Simultaneously

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Abstract Topology optimization is a powerful tool for the conceptual design of engineering structures. As strength, stiffness, and stability are three of the most important characteristics of structures to be considered during the design process, they should be taken into account in the problem formulation of structural optimization through either objective function or constraint conditions. Over the years, most studies in topology optimization have been conducted by considering just structural compliance, and only recently, stress and buckling optimizations have drawn more and more research attention [1-4].

In this paper, an optimization formulation for minimizing the structural compliance considering constraints on material volume, von Mises stress, and buckling load factors simultaneously is presented. The SIMP (Solid Isotropic Material with Penalization) material model is used for topology optimization and a hybrid stress element is employed in the structural analysis.

A common problem when the SIMP model is used for the eigenvalue optimization problem is the appearance of pseudo eigenmodes in low-density regions, which may mislead optimization and produce erroneous results. To eliminate the detrimental effects of pseudo eigenmodes, different interpolation functions for stiffness and geometrical stiffness are used, and the method combining the eigenvalue shift and pseudo mode identification techniques is used to further remove the possible pseudo modes [4]. In addition, modes switch or multimode may appear during the optimization process, and the associated eigenvalues are nondifferentiable at that time. To circumvent such difficulties in sensitivity analysis of the buckling load factors, a smooth KS aggregation function is constructed by several low order buckling load factors to approximate the smallest buckling load factors [5] and replaces the original possibly non-smooth buckling constraints.

As for the stress constraints, the *pq* relaxation technology [6] is used to overcome the singularity phenomenon. Due to the local nature of structural stress, a large number of stress constraints are to be considered, which may require significant computation resources and times. To improve the solution efficiency, the KS aggregation function is used to approximate the maximum von Mises stress [7]. Moreover, the stress correction scheme [1] is employed to achieve an accurate evaluation of the maximum stress and stable convergence.

Numerical experience shows that designs obtained using a fixed penalization factor may produce local optima and even very poor ones [4, 8]. Thus, a heuristic continuation penalization method is used. To avoid the checkboard and obtain black-white designs, the linear and nonlinear threshold projection techniques [9] are employed. Numerical examples are presented to demonstrate the effectiveness of the proposed method.

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