Continuum structural topological optimizations with stress constraints based on stress gradients and a normal density function

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Abstract

Stress related problems have not been given the same attention as the minimum compliance topological optimization problem in the literature. Continuum structural topological optimizations with stress constraints are of wide engineering application prospect, and in which there still are many problems to solve, such as stress concenstration, an equivalent approximate optimization model and etc.. A new and effective topological optimization method of continuum structures with the objective function being the structural volume and the constraint functions being stresses has been presented in this paper. First, in the proposed method，in order to representing stresses highly nonlinear dependence on the design variables, stress gradients and several similar normal density functions are introduced to build a stress gradient measure function and some structural stress measure functions respectively as a gathering stress gradient constraint function and smooth gathering stress constraint functions with huge different distribution values over the structural design domain to control stress concentrations and all local stresse. And an equallent approximate reduced constraint structural topological optimization model with stress constraints is constructed，being incorporated with the solid isotropic material with penalization (SIMP), a varying constraint limit scheme, a trust region scheme and an effective local stress approach like the qp approach to resolve the stress singularity phenomenon. Second, a set of stress quadratic explicit approximations is constructed, based on stress sensitivities and the Method of Moving Asymptotes (MMA). A set of algorithm for the one level optimization problem with artificial variables and a lot of possible non-active design variables, is proposed by adopting an inequality constrained nonlinear programming method with simple trust regions, based on the primal-dual theory, in which the non-smooth expressions of the design variable solutions are reformulated as smoothing functions of the Lagrange multipliers by using a novel smoothing function. Third, a two-level optimization design scheme with varying constraint limits, is proposed to deal with the gathering stress constraints that always are of loose constraint (non active constraint) features in the conventional structural optimization method.

Finally, a new structural topological optimization method with stress constraints and its algorithm are formed, and examples are provided to demonstrate that the proposed method is feasible, very effective and efficient for solving the continuum structural topological optimization problems with the objective function being the structural volume and the constraint functions being stresses. And its topological configurations obtained in the proposed optimization process are similar to the topological configurations obtained by the soft-killer BESO method.

Keywords: Topological optimization; Stress constraint; Continuum structure; stress gradient ; normal density function; varying stress limits.