Optimal topology design of continuum structures with stress concentration alleviation via level set method

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Abstract

Although the phenomenon of stress concentration is of paramount importance to engineers when they are designing load-carrying structures, stiffness is often used as the solely concerned objective or constraint function in the studies of optimal topology design of continuum structures. Sometimes this will lead to optimal designs with severe stress concentrations which may be highly responsible for the fracture, creep and fatigue of structures. Thus, considering stress-related objective or constraint functions in topology optimization problems is very important from both theoretical and application perspectives. It has been known, however, that this kind of problem is

very challenging since several difficulties must be overcome in order to solve it effectively. The first difficulty stems from the fact that stress constrained topology optimization problems always suffer from the so-called singularity problem. The second difficulty in stress-related optimization problem is due to the high computational cost caused by the large number of local stress constraints. The conventional treatment of this difficulty with use of the so-called global stress measures cannot give an adequate control of the magnitude of local stress level. The third difficulty is related to the accuracy of stress computation which is greatly influenced by the local geometry of structure.

The aim of the present work is to develop some effective numerical techniques for designing stiff structures with less stress concentrations. This is achieved by introducing some specific stress measures, which are sensitive to the existence of high local stresses, in the problem formulation and resolving the corresponding optimization problem numerically in a level set framework. In the first global stress measure, local geometry information such as boundary curvature is introduced while in the second global stress measure, stress gradient is employed to locate the hot points of high local stresses automatically. Our study indicates that with use of the proposed numerical schemes and proposed global stress measures, the intrinsic difficulties mentioned

above in stress-related topology optimization of continuum structures can be overcome in a natural way.

Keywords: Topology Optimization; Stress concentration; Level set; Extended finite element method (X-FEM)