An enhanced aggregation method for stress-constrained topology optimization problems

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Abstract:

For the topology optimization with local stress constraints on all the elements, conventional "global constraint methods" may introduce high nonlinearity to the global constraint function and cannot adequately control the local stress state. This study aims to develop an enhanced aggregation method that not only effectively reduces the number of constraints in the search process, but also ensures sufficient accuracy of the solution for the SIMP-based topology optimization. By introducing a new reduction parameter into the Kreisselmeier-Steihauser (K-S) function, a new general K-S formulation is suggested for aggregating the local constraints that are active at the optimum. The approximation of the general K-S function to the feasible region restricted by active constraints is proved to be highly accurate even when the aggregation parameter takes a relatively small value. Numerical difficulties, such as high nonlinearity and serious violation of local constraints that may be exhibited by the original K-S function, are thus effectively alleviated. In the considered topology optimization problem, the material volume is to be minimized under local von Mises stress constraints imposed on all the finite elements. An enhanced aggregation algorithm based on the general K-S function, in conjunction with a "removal and re-generation" strategy for selecting the active constraints, is then proposed to treat the stress-constrained topology optimization problem.

With a purely mathematical optimization problem, it is demonstrated that the enhanced aggregation method outperforms the conventional global approaches based on the original K-S function. The solution obtained by the proposed method matches the exact optimum well even when a small aggregation parameter is used. Several topology optimization examples with large number of local stress constraints are also presented for illustrating the efficiency of the enhanced aggregation method. It is shown that excellent solutions that are fully stressed without any violation on local stress constraints can be obtained at reasonable computational efforts.