11th. World Congress on Computational Mechanics (WCCM XI)
5th. European Conference on Computational Mechanics (ECCM V)
6th. European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 – July 25, 2014
Barcelona, Spain

Revisiting approximate reanalysis in topology optimization

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ABSTRACT

An efficient procedure for three-dimensional continuum structural topology optimization is presented. The approach is based on utilizing approximate reanalysis techniques, essentially performing a fully accurate structural analysis only at selected design cycles and faster reanalysis otherwise. It is shown that integrating reanalysis into a minimum volume problem formulation can lead to a more efficient procedure than the common minimum compliance approach.

Consistent integration of approximate reanalysis techniques into continuum topology optimization was first presented by Amir et al. [1], who followed Kirsch's Combined Approximations (CA) approach to structural reanalysis [e.g. 2]. The purpose of the current study is to revisit the utilization of CA in topology optimization and to offer significant improvements with respect to its computational efficiency. It is shown that once reanalysis is employed, it is advantageous to use a minimum weight problem formulation. This is in contrast to the original study where the minimum compliance objective was considered. The underlying reason for the superior performance of the minimum volume formulation is the exploitation of *stiff preconditioning*, originally suggested in the context of robust topology optimization [3].

While the savings compared to standard approaches are rather modest in 2-D applications due to the efficiency of direct solvers, the reanalysis-based approach offers significant reduction in computational effort in 3-D problems. A multigrid preconditioned conjugate gradients (MGCG) framework for topology optimization [4] is utilized for the 3-D extension of the proposed reanalysis-based minimum volume procedure. During "accurate" design cycles in 3-D optimization, a fully accurate MGCG solve is performed instead of a Cholesky decomposition in 2-D optimization. In subsequent "reanalyzed" design cycles, the coarse grid operators are reused for preconditioning the equation systems. Therefore both matrix assembly and generation of the multigrid components are avoided, resulting in a very efficient procedure.

Numerical experiments focus on various three-dimensional problems involving hundreds of thousands DOF. Implemented in MATLAB, the run time is roughly twice faster than that of standard minimum compliance procedures. For example, 50 design cycles of a 3-D bridge with over 160,000 DOF are completed in less than 3 minutes on a single processor. The same problem is solved in nearly 6 minutes by the minimum compliance MGCG procedure. Computational savings are achieved without any compromise on the quality of the results in terms of the compliance-to-weight trade-off. This provides a step towards integrating interactive 3-D topology optimization procedures into CAD software and mobile applications.

References

[1] O. Amir, M. P. Bendsøe, and O. Sigmund. "Approximate reanalysis in topology optimization". In: *International Journal for Numerical Methods in Engineering* 78 (2009), pp. 1474–1491.

[2] U. Kirsch. *Reanalysis of Structures*. Dordrecht: Springer, 2008.

[3] O. Amir, O. Sigmund, M. Schevenels, and B. Lazarov. "Efficient reanalysis techniques for robust topology optimization". In: *Computer Methods in Applied Mechanics and Engineering* 245-246 (2012), pp. 217–231.

[4] O. Amir, N. Aage, and B. S. Lazarov. "On multigrid-CG for efficient topology optimization". In: *Structural and Multidisciplinary Optimization* (2013). In press.