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 - 25, 2014, Barcelona, Spain

Stress-related topology optimization of continuum structures involving multi-phase materials

W.S. Zhang [1]* W.L. Zhong [1] and X. Guo [1]

[1] State Key Laboratory of Structural Analysis for Industrial Equipment,
Department of Engineering Mechanics,
Dalian University of Technology, Dalian, 116023, P.R. China,
weishengzhang@dlut.edu.cn

Key Words: *Topology optimization; Stress constraints; Level-set; Shape derivative; Extend Finite Element (X-FEM).*

Considering stress constraints in structural topology optimization is very important from both theoretical and application perspectives. Although remarkable achievements have been made for stress-related topology optimization problems, it is worth noting that most of the studies mentioned above are devoted to the problems with single-phase homogenous materials. In modern engineering applications, however, the consideration of structures made in multi-phase materials is unavoidable and has become increasingly concerned. From theoretical point of view, designing structures composed of multi-phase materials can also be formulated as a topology optimization problem, where optimal multi-phase material distribution is sought for. Compared to black-and-white topology optimization where only single-phase material is considered, however, topology optimization involving multi-phase materials is more difficult to deal with since the typical challenges in topology optimization, such as topology description parameterization, boundary blurring control and accurate stress computation, are more severe in the latter case. Furthermore, it is very difficult or even impossible to guess the optimal topology of multi-phase materials based on engineering intuitions. In the present paper, stress-constrained topology optimization of continuum structures involving multi-phase heterogeneous materials is investigated. A level-set based variational consistent solution framework is developed. Numerical examples demonstrate the effectiveness of the proposed approach. Furthermore, we have also shown that how to perform shape sensitivity analysis from pure Eulerian description point of view and the usefulness of this approach for dealing with the optimization problems involving multi-phase materials.

REFERENCES

[1] M.Y. Wang, X.M. Wang, D.M. Guo, A level set method for structural topology optimization, *Comput. Method Appl. Mech. Engrg.* Vol. **192,** pp. 227–246, 2003.

[2] G. Allaire, F. Jouve, A.M. Toader, Structural optimization using sensitivity analysis and a level set method, *J. Comput. Phys*. Vol. **194**, pp. 363—393,2004.

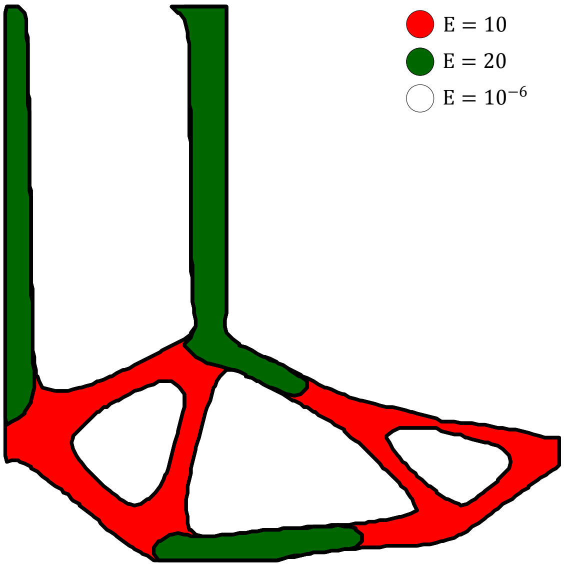
[3] M.Y. Wang, X.M. Wang, "Color" level sets: a multi-phase method for structural topology optimization with multiple materials, *Comput. Method Appl. Mech. Engrg.* Vol. **193**, pp. 469–496, 2004.

[4] S.K. Chen, S. Gonella, W. Chen , W. K. Liu, A level set approach for optimal design of

smart energy harvesters, *Comput. Methods Appl. Mech. Engrg.* Vol. **199**, pp. 2532–2543, 2010.

[5] M.Y. Wang, X.M. Wang, Y.L. Mei, S.K. Chen, Design of multi-material compliant mechanisms using level-set methods, *J. Mech. Design* Vol. **127**, pp. 941-956, 2005.

[6] Z. Luo, L. Tong, J. Luo, P. Wei, M.Y. Wang, Design of piezoelectric actuators using a multiphase level set method of piecewise constants, *J. Comput. Phys.* pp. 2643–2659, 2009.



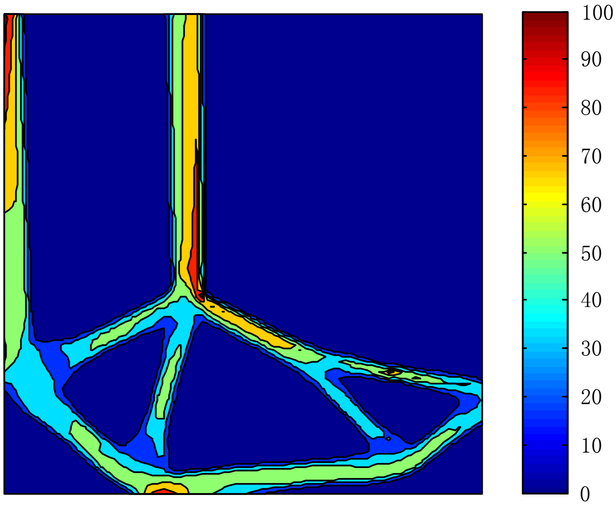


Fig. 1 Optimal design of the L-shape beam problem and the corresponding stress distribution under formulation Eq. (3.2) with $E^1 = 20$, $E^2 = 10$ (Young's moduli) and $\bar{\sigma}^1 = \bar{\sigma}^2 = 100$ (allowable stresses) respectively.