Optimum Shape and Topology Design of Shell Structures by H^1 Gradient Method

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Abstract

In this paper, we propose a parameter-free simultaneous shape and topology optimization method for designing a shell structures with single or multi-materials. By implementing topology optimization in the variable design domain which is optimized by shape optimization at each iteration, the optimal topology and shape can be simultaneously determined [1]. The GSIMP method [2] and the free-form optimization method for shells [3] are used as topology and shape optimization method, respectively. Compliance is used as the objective functional. The volumes of two materials and the surface area of the shell are used as the constraint functionals for topology and shape optimization, respectively. The fictitious density and the out-of-plane shape variation are employed as the design variables. The optimum design problem is formulated as a distributed-parameter optimization problem based on the variational method, and the sensitivity functions for density and shape variations are theoretically derived. Both the optimal density distribution and the optimal shape variation are determined by the H^1 gradient method [1][3], where the sensitivity functions are applied as the Robin condition to vary the shape and density. With the proposed method, the compliance is minimized while maintaining the smoothness of the surface shape and the density distribution. Fig. 1 shows the calculated results of a torsion box for various combinations of shape and topology optimization. (a) shows the initial shape and the boundary conditions. The obtained results are shown from (b) to (e): (b) and (c) are for only shape and topology optimization, respectively, (d) is for two step optimization (i.e., from "shape" to "topology"), (e) is for simultaneous optimization, and is stiffer than (d). With the proposed method, lighter and stiffer shell structures can be designed without design parameterization and numerical instabilities.

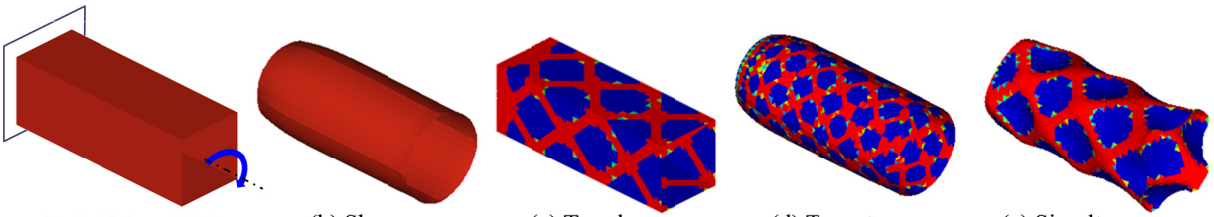

Fig. 1 Comparison of calculated results by various optimization methods

References

[1] H. Nakayama and M. Shimoda, "Simultaneous shape and topology optimization method based on the H1 gradient method for creating light weight plate and shell structures", *Transactions of the JSME (in Japanese)*, Vol. 84, No. 858, DOI: 10.1299/transjsme. 17-00484, 2018.
[2] M. Bendsøe and O. Sigmund, "Material interpolation schemes in topology optimization", *Archive of Applied Mechanics* vol. 60, pp. 635-654, 1999.
[3] M. Shimoda and Y Liu, "A Non-parametric free-form optimization method for shell Structures", *Structural and Multidisciplinary Optimization* vol. 50, pp. 409-423, 2014.