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Numerical study of avoiding mechanism issues in structural topology optimization

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Abstract

In paper [1], the 99-line topology optimization code from paper [2] was fully used by us. Based on a large number of examples computed by using the 99-line code, choosing an objective function and constraints was discussed for model construction of structural topology optimization, to develop a 120-line topology optimization code at the same time. We have pointed out: in the consideration of mutual coordination and appropriate selection of the objective function and constraints, it's better to select an economic indicator as an objective function and structural mechanical performance indicators as constraints for a more reasonable optimization model. This selection approach can avoid structural degeneration into mechanisms and obtain safe structural designs. Conversely, if a structural mechanical indicator, such as the structural compliance, is taken as an objective function, and the structural volume ratio is taken as a constraint at the same time, due to the dependency of the optimal topological configurations on values of the volume ratios, the structure will be broken off or disconnected and degenerate into a mechanism when the value of the volume ratio is too small.

Because of the limited length of paper [1], it didn't involve another question: can the mechanisms be avoided proactively when the 99-line topology optimization code is used in structural topology optimization? If this question could be answered, two benefits may be obtained: (1) satisfying needs of the theory development of structural topology optimization; (2) providing effective help for users of the 99-line topology optimization code. Therefore, the present paper continues the research of paper [1]. Situations in structural topology optimization, where mechanisms appear, are specifically explored in this paper. In these situations, the respective changes of the structural volume ratios and the strain energy are investigated to look for the numerical rules that cause mechanisms in structural topology optimization.

For the optimization problem of the MCVC (minimum compliance with volume constraint), based on the 99-line code in paper [2], this paper calculates a large number of morbid examples with mechanisms appearance by referring to the 120-line code of the solution for the MWDC (minimum weight with displacement constraint) in paper [1]. In each example, besides the volume ratio of the final optimal configuration to the ground structure, the maximum value of the ratios of the strain energy of each configuration in iterative process to the strain energy of initial ground structure with full materials is investigated. It is found out that, the mechanism will occur when the maximum strain energy ratio is larger than a threshold, or when the volume ratio is less than a threshold. Both of the two thresholds can vary for different structures and/or loading cases, but for those particular examples that we tested, the range of the threshold for the maximum strain energy ratio turns out to be between 4.5886 and 12.3791, and the range of the threshold for the volume

ratio is between 0.15 and 0.26. Researchers of structural topology optimization and engineers can use above numerical rules to prevent mechanisms appearance in the optimal topological configurations. This work will help them to avoid unadvisable constraint values, which cause mechanisms, and to use advisable constraint values for calculation in structural topology optimization.

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Reference:

[1] Y. K. Sui, G. L. Yi (2012) A discussion about choosing an objective function and constraints in structural topology optimization. 10th World Congress on Structural and Multidisciplinary Optimization (in reviewing) MATLAB code available online at www.sites.google/yiguilian/link

[2] O. Sigmund (2001) A 99 line topology optimization code written in MATLAB. Struct Multidisc Optim 21:120–127. DOI 10.1007/s001580050176, MATLAB code available online at www.topopt.dtu.dk