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Robust topology optimization of slender structures with geometric imperfections

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1. Abstract

In recent times structural optimization has become an important part of the design process in engineering. Topology optimization is a powerful tool in this respect as it simultaneously optimizes the size, shape and topology of a design, often resulting in new and original designs. The designer only has to specify an appropriate design domain that contains the structure. The optimal distribution of material in this domain is determined by means of a numerical optimization algorithm. This work considers design optimization of mechanical and civil structures by means of the density based approach for the topology optimization. The Solid Isotropic Material Penalization (SIMP) method is adopted for favoring discrete designs and projection filters are utilized for limiting the geometric complexity of the design.
Optimized designs typically form efficient and economical solutions. However, structural design by means of topology optimization often leads to slender structures which are sensitive to geometric imperfections such as the misplacement or misalignment of material. A feasible design should be sufficiently robust with respect to variations in the system. This work therefore presents a robust approach which incorporates geometric imperfections in the topology optimization problem. Material misplacement can be modeled by either distorting the finite element mesh or by adding a small perturbation to the center of the density filter kernel on a fixed mesh [1]. A nonlinear elastic formulation is adopted in order to take into account geometric nonlinear behavior such as $P - \Delta$ effects in slender compressed elements.
The spatial variation of the geometric imperfections is modeled by means of a vector-valued Gaussian random field. The random field is conditioned in order to incorporate fixed supports for the structure. In the robust optimization problem, the objective function is defined as a weighted sum of the mean value and the standard deviation of the performance of the structure under uncertainty. In the optimization algorithm, the statistical moments and the corresponding design sensitivities are estimated by means of a sampling method.
The presented method is applied successfully in the robust design of several mechanical structures. The solutions obtained by the robust approach are validated by means of an extensive Monte Carlo simulation.

10. References

[1] M. Jansen, G. Lombaert, M. Diehl, B.S. Lazarov, O. Sigmund, and M. Schevenels. Robust topology optimization accounting for misplacement of material. *Structural and Multidisciplinary Optimization*, 47:317–333, 2013.