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Multiscale Topology Optimization of Buckling-resistant Structures

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Multi-scale structures, achieving extreme and tuneable performances while being lightweight, are gaining increasingly more interest. For example, lattice materials and infilled structures have already proven to be more competitive than classical, single-scale, composites for some automotive and aerospace applications. On the other hand, the multiscale idea has recently gained popularity as a computational tool speeding up structural topology optimization. Stiffness optimized designs consisting of millions of design variables have been obtained at a remarkably low computational cost, by coupling traditional homogenization-based topology optimization with a de-homogenization step interpreting the optimized set of material properties with a single-scale structure [1].

Extending this method to the design of buckling resistant structures is the topic of this work. To do this, difficulties arising when including buckling in the analysis and design of multiscale structures must be overcome. First, analytical solutions and theoretical bounds are not known for the buckling response, and the optimized unit cells must be found numerically. Second, such unit cells show a high dependence on the stress state, making very complicate to achieve a stable design under multiple load conditions [2]. Finally, the de-homogenization is made challenging by the presence of many simultaneous, local buckling modes [3] and stress concentrations, potentially disrupting the performance of the infill.

A thorough analysis of the origins and effects of these issues is given, possible remedies are discussed, and multiscale designs optimized for extreme buckling resistance are shown.

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