

TRUSS TOPOLOGY OPTIMIZATION CONSIDERING CHAIN EFFECTS IN LOCAL BUCKLING

Fábio Conde, Cláudia Almeida, Pedro Coelho, Guilherme Rodrigues, Hugo Biscaia

UNIDEMI: Research & Development Unit for Mechanical and Industrial Engineering

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Abstract

Truss structures are among the most efficient load-carrying systems in engineering, as their members carry forces solely through axial tension and compression. This structural efficiency leads to remarkable stiffness-to-weight ratios, which explains the widespread adoption of trusses in demanding lightweight applications ranging from aerospace systems to long-span civil structures. In such applications, however, feasible designs require the careful consideration of stress and buckling criteria.

In this work, topology optimization based on the ground structure approach is employed to obtain efficient truss layouts while accounting for strength and stability requirements. To address stability, local buckling criteria are considered. However, ground structure design domains present a particular challenge, since collinear members may become interconnected and behave as a single continuous element, forming chains whose effective buckling length must be properly evaluated.

A novel methodology is proposed to handle chains in the framework of gradient-based optimization. Mass and compliance minimization formulations, with local stress and buckling constraints, are explored. The design variables are divided into two groups: artificial density variables controlling the existence of members and cross-sectional area variables defining their size. This hybrid parametrization facilitates the identification of chains, enforces minimum member areas and alleviates the singularity issues typically associated with local buckling constraints. Member stability is evaluated using either Euler or Euler–Johnson predictions. To avoid the emergence of kinematically unstable topologies, the compliance minimization problem is solved considering multiple load cases.

Numerical examples validate the proposed approach, showing that the effective buckling length of chains is correctly captured in the optimized layouts. Differences between mass- and compliance-driven designs are observed. The Euler–Johnson formulation is advantageous in the optimization process, as the optimal member slenderness is not known beforehand and safer solutions may be obtained when members exhibit lower slenderness. Moreover, the use of multiple load cases in compliance minimization promotes kinematically stable structural topologies.

Beyond conventional structural design at the macroscale, the proposed methodology opens new possibilities for instance in the systematic design of lattice-based architected materials. Its extension to the microstructural design is straightforward and may enable the development of metamaterials with enhanced mechanical performance and feasible in terms of buckling.

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