

TOPOLOGY OPTIMIZATION OF ELASTO-PLASTIC STRUCTURES WITH PERMANENT RESPONSE

Mathias Wallin, Gunnar Granlund

Lund University

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Abstract

We present two complementary advances in topology optimization (TO) for elasto-plastic structures that deliberately exploit inelasticity to achieve new functionalities and broaden stiffness design objectives. First, we introduce a TO framework for designing compliant self-locking mechanisms that maximize a targeted permanent, unloaded deformation after a single load/unload cycle. The small-strain elasto-plastic state problem incorporates kinematic hardening to capture the Bauschinger effect and accurately model reverse loading and spring-back. Regularization using a PDE filter with Robin boundary conditions together with Heaviside projection produces crisp, mesh-independent 3D designs. Numerical demonstrations include a permanent compliant gripper and a compression-to-torsion converter, both deliberately developing plasticity along prescribed load paths to achieve one-time self-locking behavior.

Second, we formulate and compare two stiffness-based objective functions for elasto-plastic TO: traditional end secant stiffness and a novel end tangent stiffness. We show that the two stiffness formulations lead to markedly different optimal designs. Secant stiffness optimization yields structures with high reaction forces but low terminal tangent stiffness due to widespread plasticity. In contrast, tangent stiffness optimization favors designs with localized plastic zones and significantly increased terminal tangent stiffness, though at the cost of reduced overall load-carrying capacity. 2D and 3D cantilever and MBB benchmarks show that the two measures can be contradictory. These findings broaden the design space for elasto-plastic TO by enabling programmed permanent deformation and by clarifying fundamental trade-offs between global load capacity and incremental stability.

References

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