

TOPOLOGY OPTIMIZATION OF BOLTED COMPONENTS CONSIDERING ASSEMBLY CONSTRAINTS AND TOOL ACCESSIBILITY

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Keywords: Topology Optimization, Mechanical Assemblies, Bolted Joints, Structural Optimization, Level-Set Functions, Implicit Functions

Abstract

Bolted components require non-negotiable void regions for bolt holes, head bearing, and tool approach. In density-based topology optimization (TO) these are often imposed as fixed passive elements, which can cut load paths and produce sharp internal corners with high stresses. This work highlights how the tooling cutout geometry significantly influences compliance, showing that accessibility assumptions can dominate the optimum.

We propose a SIMP-based routine that co-optimizes the density field and parametric accessibility voids around candidate bolt positions. Bolt holes and bearing surfaces are embedded as void/solid subdomains; the tool-access void is parameterized covering (i) torque-wrench openings, (ii) screwdriver tilt/rotation, and (iii) curved insertion channels for captive nuts. Each void is defined by a signed-distance function (SDF) and converted into a smooth Heaviside/logistic mask, yielding a differentiable exclusion. Cutouts also raise peak stress and increase sensitivity to residual stresses (e.g., from machining or additive post-processing) at the cutout boundary. We therefore enforce a minimum length scale on the void phase and add local rounding directly in the SDF, as well as morphology-based filtering near the cutout boundary.

The present work delivers topology-optimized components with guaranteed bolt accessibility and limited stress concentration, thanks to the incorporation of parameterized cutouts in the optimization routine. The method allows for tool accessibility constraints from open manual access to robotics and automated assembly, closing the gap between structural TO and assembly planning for bolted components.