

APPLICATION OF A MACHINE LEARNING-BASED TOPOLOGY OPTIMIZATION METHOD ON AN AUTOMOTIVE B-PILLAR FOR CRASHWORTHY LIGHTWEIGHT DESIGN

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Abstract

Topology optimization methods are established in engineering. However, in application areas such as crashworthiness design, gradient-based methods face major challenges, e.g., due to nonlinearities in geometry, material, and contact phenomena. Utilizing sensitivities is either computationally expensive or infeasible. Therefore, many non-gradient methods have been developed to tackle those challenges, including the Graph- and Heuristic based Topology Optimization (GHT) or the Hybrid Cellular Automaton (HCA) method. This work applies a machine-learning-based topology optimization method, named voidML, to the lightweight design of an automotive B-pillar assembly. The study focuses on the reinforcement sheet component of the B-pillar, where mass is reduced by introducing voids while aiming to retain the structural behaviour of the reference design under crash loading. The B-pillar assembly is tested in FE model of a test rig and is subjected to a side-impact load case.

The method voidML was developed for thin-walled structures and uses local state information from finite-element crash simulations to guide topology changes. For each element, features such as internal energy density, principal strain components, and stress are extracted from the current design state and provided to a Gradient Boosted Decision Tree (GBDT) model. The model is used to estimate the influence of local void insertions on the structural response. Based on these predictions, candidate void locations are selected and combined into competing design variants, which are then evaluated and ranked according to the optimization objective and the imposed constraints.

The approach is applied to a B-pillar reinforcement model to investigate whether data-driven void placement can achieve meaningful mass reduction while preserving the crash-relevant response of the structure. The contribution of the work is the transfer of the method from an academic demonstration case to an automotive component and the assessment of its suitability for lightweight design of crash-loaded thin-walled structures.