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A hybrid approach to structural topology optimization of vehicle for crashworthiness

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Structural topology optimization of vehicle for crashworthiness is a challenging subject because it involves geometric and material nonlinearity as well as transit dynamic analysis. The existing study in structural topology optimization mostly focuses on static analysis of the linear elastic structure. The difficulty of gradient calculation in crashworthiness design problem constitutes a major obstacle to apply the existing topology optimization methods such as homogenization method and SIMP method. HCA (hybrid cellular automata) approach is one of heuristic approaches and does not need gradient information to get a crashworthiness topology optimum design. Each execution of HCA iteration needs a complete crashworthiness analysis to obtain the yield parameters for the update rule of design variables, which renders the method high computational cost. The well-known inertia relief method has been applied in analysis and design of free-free vehicle under impact load in aerospace industry for many years. It replaces the transit dynamic analysis by approximate static analysis under the impact load and inertia load. However, in car collision event the magnitude and spatial distribution of the impact load is unknown in prior and depends on the structure being crashed. The present study proposes a hybrid approach by integrating the improved inertia relief method with HCA. To estimate the magnitude and spatial distribution of the impact load during the crash event, a new spring-mass model is constructed. Its accuracy is studied by using more complicated models including the multiple mass-springs in series model and continuum model with nonlinearity. A number of transit dynamic nonlinear analyses are carried out occasionally to find the magnitude and spatial distribution of the impact load for the initial design and the improved design. The structural topology optimization is obtained iteratively under the given impact load with the inertia relief method, nonlinear static analysis and HCA approach. A simplified car model example is tested to show the effectiveness and efficiency of the hybrid approach.

Keywords: Crashworthiness, Energy absorption, Inertia relief, Topology Optimization