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Optimization of Automotive Composite Structures for Crash

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Abstract

Composites in automotive structures show great promise; composites have been shown to be lightweight, more robust and have superior crash performance [1, 2]. The high specific strength and stiffness of advanced composites may have a significant influence on the overall weight reduction in automotive structures. Until now limited research has been done on optimal design of composite structures for crash. The large differences in material properties and failure behavior between metals and composites may however require a significant redesign of vehicle architectures. Replacing components in existing architectures with composite parts does not use the full potential of advanced composites. Commonly used steel, aluminum and other isotropic materials have already been extensively researched with respect to their material properties, static and dynamic behavior and simulation [3]. By contrast, there are no complete and well established material databases for fiber reinforced plastic (FRP) composite materials, which support reliable and validated simulation. However, simulation of FRP in an optimization work flow is possible when the limitations and possibilities of current analysis tools are carefully assessed and considered. Novel methods in optimization strategy are needed to integrate advanced composite materials in automotive design.

This paper presents such a method to optimize automotive composite structures for crash. First a sensitivity analysis is presented that identifies the critical parameters in composite structure optimization for increased crashworthiness and reduced weight. Both structural sizing and material parameters are investigated; Lamination Parameters (LP) [4, 5] and laminate thickness are used to describe the material stiffness properties and with the use of SFE CONCEPT *[6] the structure geometry sizing is parameterized. With the use of* CZONE *[7], a finite element method (FEM) approach for composite crush analysis, the crush failure in the impact zone is simulated. These methods are combined in a work flow, which robustly couples the parameters and the Finite Element (FE) models. An adapted Ant Colony Optimization implementation for continuous design spaces (ACOR) [8] is used to optimize the geometry and material parameters of the structure.*

The method is demonstrated on a S-rail structure, a typical and important sub-structure located in the front of the automotive architecture. The S-rail has three purposes: 1. Energy absorption as it is the major component in the vehicle front and should take over most of the kinectic energy. 2. Increase of the overall stability and deformation resistance of the safety cell. 3. Provide sufficient stiffness and strenght to carry the motor and other core vehicle components. Structural size optimization has been done on this structure with metallic materials, but not yet for composites [9, 10]. Furthermore, the optimization methodology as presented in this paper, shows improvements over previous attempts, by first determining critical parameters, including shape parameters, with the use of a sensitivity analysis and secondly assessing the structural stability before doing a costly explicit FEA. Each design experiment is analyzed with a static linear buckling analysis to assess the global stability of the structure, thereby splitting the design space, where only stable structures are analyzed with computationally expensive explicit methods.

The proposed approach aims to further the understanding of advanced composite structures during crash in a simulation environment. It will be shown that the global stability of the structure has a significant influence on the crashworthiness of the total structure. The optimization work flow shows that automated creation of optimal composite structures for crash is possible and can be done efficiently.

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