Development of Novel CFRP Vehicle Architectures

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Introduction
Carbon Fibre Reinforced Plastic (CFRP) composites allow lightweight automotive structures with often superior crash performance [1, 2]. CFRP components show typical Specific Energy Absorption (SEA) values between 60 to 70 kJ/kg, which is two to three times higher when compared to commonly used metals [3].

Therefore, CFRP composites in automotive structures show great promise to further improve vehicle crashworthiness. However, designing automotive structures for crash with advanced composite materials is challenging. The large amount of design parameters for laminated composites, the complex non-linear material behaviour and the discontinuous design space in vehicle design, such for crashworthiness, are the main contributors to this challenge. Consequently, use of CFRP in vehicle design requires new vehicle concepts as well as design methods in the early design phase of a vehicle, both of which are not available.

In this PhD research project, we propose hence a new design strategy to address this and integrate advanced laminated composite materials in automotive design for crashworthiness.

Proposal
This work will address this by providing a detailed study of the impact of design decisions on an architectural level on the relative crash performance of vehicles, to deliver updated vehicle architectures. In the course, the vehicle architecture is studied for frontal and side loading to arrive at an optimized architecture for several relevant load cases. Secondly, the shape and layup of individual CFRP components is studied and optimized to generate a vehicle design with high crash performance.
Optimum Architecture
The Level-Set-Method (LSM) [4] for structural shape and topology optimisation is used to derive optimal load paths for CFRP composite vehicle architecture. The transient dynamic property of the load in a crash case is represented by an adapted Equivalent Static Loading (ESL) method. The different load cases, related to different crash scenarios, are represented by a multi-load optimization (MLO) approach. A local volume constraint approach is adopted to control the material distribution during optimization.

Component and Subsystem Optimization
The second stage of the optimization framework is concerned with deriving an optimum CFRP composite sub-system. The optimized load path is used as a basis for an early phase concept. To reliably optimise this concept, a two phase complexity reduction method is applied [5]. The final efficiently parameterized design with reduced solution space is put through a sizing optimisation approach to achieve a crashworthy CFRP vehicle concept.

References


Fig 1: LSM for Vehicle relevant MLO problems