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MULTI-OBJECTIVE OPTIMIZATION STUDY OF A PARAMETRIC VEHICLE BUMPER SUBSYSTEM SUBJECT TO UNCERTAINTY

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ABSTRACT - This paper deals with the design and optimization of a vehicle bumper subsystem, which is a key scenario for vehicle component design. More than ever before, the automotive industry operates in a highly competitive environment. Manufacturers must deal with competitive pressure and with conflicting demands from customers and regulatory bodies regarding the vehicle functional performance and the environmental and societal impact. Since also the time to market must be reduced, this forces them to develop products of increasing quality in even shorter time. As a result, bumper suppliers are under pressure to increasingly limit the weight, while meeting all relevant design targets for crashworthiness and safety. To succeed in such a challenging environment, manufacturers address the complex design problems by means of virtual modelling and simulation procedures that enable optimizing the performance of such subsystems as early as possible in the design timeline. For the bumper design challenge, an integrated methodology for multi-attribute design engineering of mechanical structures is set up. The integrated process captures the various tasks that are usually performed manually, this way facilitating the automated design iterations for optimization.

The bumper subsystem is important in the energy management of vehicles during low-speed accidents. By combining an automated process with optimization technology, one can efficiently balance between different performance attributes. As a first step, the structural bumper model is created, parameterizing its geometric and sectional properties. A Design of Experiments (DOE) strategy is then adopted to efficiently identify the most important design parameters. Subsequently, an optimization is performed on efficient Response Surface Models (RSM), in order to minimize the vehicle bumper weight, while meeting all design targets. In particular, the optimized bumper design with respect to crashworthiness performance will be presented.

Furthermore, it is noted that in any mechanical design process, there is non-determinism in certain design parameters, so that the product performance will actually have a certain range rather than a sharply defined value. The non-determinism can be quantified as uncertainty (i.e. lack of information on certain parameters) or variability (e.g. the inevitable geometrical and material differences between nominally identical products). For a thorough understanding of the product performance, it is important to validate the performance of the optimized bumper subsystem considering the actual non-determinism in the product definition. In this paper, this rationale is worked out for the optimized bumper design with uncertainty in the geometry and shell thickness definitions. A fuzzy analysis approach based on the α-cut strategy for assessing the effect of the input uncertainty is applied.

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