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Contribution to the design and the optimization of adaptative restraint systems to improve the automotive passive safety

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In the last years, automotive safety became a major issue for the car manufacturers due to its growing importance in their marketing strategy. This comes on the top of a strong political will to reduce the fatalities due to road accidents. In this perspective, newly developed adaptive restraint systems are in the starting blocks to play an important role.

This PhD thesis aims at presenting the design and optimization of an adaptive restraint system using numerical simulation. This study relies on three years of simulations and experiments by the Group Research of Daimler AG in the department Assistance and Safety Systems. The first step of this study was to identify frontal crash as the load case likely to be optimized and then to evaluate the restraint system components to be involved to introduce adaptability in the restraint system. The passenger airbag has been chosen as object to bring the adaptability into the restraint system. Contrary to state-of-the-art restraint systems, the optimization method proposed here focused on the adaptability and not only on the restrain performance. To this aim, an adaptability tensor including load cases enabling the adaptability assessment of a restraint system as well as an adaptability score accounting for its adaptability level have been defined.
This thesis intends to introduce adaptability in the restraint system by implementing two distinct principles: the variable damping and the earlier coupling of the occupant. Variable damping has been realized by controlling the gas flowing out of the airbag through adaptive vents which trigger time or exhaust orifice sizes. Self-adaptive vents have also been considered. This method proves profitable when it comes to use all the available distance to stop the occupant. Earlier coupling involves the implementation of an airbag whose shape and volume could be adapted to the crash conditions. This principle shows excellent results with occupants sitting in middle to rear-most seat track positions. A numerical simulation model associating variable damping and earlier coupling has been evaluated according to the adaptability tensor. The simultaneous use of both principles leads to an increase of the performance but above all of the adaptability level of the restraint system.

The spread of adaptive restraint systems and especially of variable airbags proved their importance towards the increase of the average safety level of the passenger whatever the crash conditions.