Design and Optimization of a Thoracic Dummy Module for the Response of Multi-directional Impact and Localized Deformation of Ribcage

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Abstract

Objective: *For the various loading environment observed in modern vehicles equipped with advanced restraint systems, literature survey and data analyses have shown that the current experimental tools for injury studies are unable to estimate the risks of thoracic injuries accurately. The objective of this study is to design and optimize a new thoracic dummy module, with focuses on realizing the localized deformation of ribcage and enabling high biofidelity under multi-directional impact.*

Problem to be solved: *The existing dummies, such as Hybrid III, ES-2 and THOR, were only designed against biomechanical responses of a particular impact direction, without consideration of multi-directional impact resulting from advanced restrain systems. In addition, the localized deformation of the ribcage and the differences of thoracic injury risks among multiple loading types are ignored among the existing dummies.*

Methods: *In this study, a new thoracic dummy module concept has been developed to meet the much more rigorous biomechanical requirements of advanced restrain systems. A demonstrator was designed and manufactured, with focuses on realizing the localized deformation of ribcage to be sensitive to the loading types and enabling high biofidelity under multi-directional impact. In addition, a series of tests were conducted to assess that whether the design can achieve the targets mentioned above. In order to optimize the responses of module, a FE model of the prototype was developed with extensive validations. To optimize the key parameters of the design, the validated Prototype FE model was scaled, improved and installed on a FE-Hybrid III dummy model. Through the Hybrid FE model with Modified Thorax Module, a matrix of simulations was undertaken to meet the biomechanical requirements and the design parameters were determined.*

Results and Discussion: *Several pendulum impactor tests were conducted with the prototype and the Prototype FE model simulations were undertaken under the same loading conditions. The results indicated that the prototype enabled ribcages to have more localized deformation. Additionally, the results confirmed the validity of the Prototype FE model and showed the feasibility of optimization using the validated FE model. Based on a set of pendulum impact simulations with the Hybrid FE Model with Modified Thorax Module, the combination of two important parameters was recommended. The results also showed that the responses of the model were almost correlated to the corridors.*

Conclusions: *This study developed a new design of thoracic dummy module with the prototype manufacture, tests and simulations. A series of tests and simulations showed that the localized deformation and good biofidelity under multi-directional impact could be realized with this module. The good correlation of the responses to the corridors in literature and the deformation shapes being sensitive to loading types, indicate the probability of a new prototype in the future.*