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Stochastic finite element simulations of real life frontal crashes

With emphasis on chest injury mechanisms in near-side oblique loading conditions.

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Akademisk avhandling

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fredagen den 5:e juni, kl. 13:00.
Avhandlingen kommer att försvaras på engelska.

Fakultetsopponent: Professor Joel Douglas Stitzel Jr, Virginia Tech-Wake Forest University School of Biomedical Engineering and Science, USA.

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Title

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Abstract

Introduction. Road traffic injuries are the eighth leading cause of death globally and the leading cause of death among young people aged 15-29. Of individuals killed or injured in road traffic injuries, a large group comprises occupants sustaining a thorax injury in frontal crashes. The elderly are particularly at risk, as they are more fragile. The evaluation of the frontal crash performance of new vehicles is normally based on barrier crash tests. Such tests are only representative of a small portion of real-life crashes, but it is not feasible to test vehicles in all real-life conditions. However, the rapid development of computers opens up possibilities for simulating whole populations of real-life crashes using so-called stochastic simulations. This opportunity leads to the aim of this thesis, which is to develop and validate a simplified, parameterized, stochastic vehicle simulation model for the evaluation of passive restraint systems in real-life frontal crashes with regard to rib fracture injuries.

Methods. The work was divided into five phases. In phase one, the geometry and properties of a finite element (FE) generic vehicle buck model were developed based on data from 14 vehicles. In the second phase, a human FE model was validated for oblique frontal crashes. This human FE model was then used to represent the vehicle occupant. In the third phase, vehicle buck boundary conditions were derived based on real-life crash data from the National Automotive Sampling System (NASS) and crash test data from the Insurance Institute for Highway Safety. In phase four, a validation reference was developed by creating risk curves for rib fracture in NASS real-life crashes. Next, these risk curves were compared to the risk of rib fractures computed using the generic vehicle buck model. In the final phase, injury mechanisms in nearside oblique frontal crashes were evaluated.

Results. In addition to an averaged geometry, parametric distributions for 27 vehicle and boundary condition parameters were developed as guiding properties for the stochastic model. Particular aspects of the boundary conditions such as pulse shape, pulse angle and pulse severity were analyzed in detail. The human FE model validation showed that the kinematics and rib fracture pattern in frontal oblique crashes were acceptable for this study. The validation of the complete FE generic vehicle buck model showed that the model overestimates the risk of rib fractures. However, if the reported under-prediction of rib fractures (50-70%) in the NASS data is accounted for using statistical simulations, the generic vehicle buck model accurately predicts injury risk for senior (70-year-old) occupants. The chest injury mechanisms in nearside oblique frontal crashes were found to be a combination of (I) belt and airbag loading and (II) the chest impacting the side structure. The debut of the second mechanism was found for pulse angles of about 30 degrees.

Conclusion. A parameterized FE generic passenger vehicle buck model has been created and validated on a population of real life crashes in terms of rib fracture risk. With the current validation status, this model provides the possibility of developing and evaluating new passive safety systems for fragile senior occupants. Further, an injury mechanism responsible for the increased number of outboard rib fractures seen in small overlap and near-side oblique frontal impacts has been proposed and analyzed.

Keywords
EDR, Real life crashes, Oblique, Finite element, Simulation, HBM, Injury mechanism, Pulse shape, Stochastic, Rib fracture, THUMS, Generic, Statistics

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