Investigating the Relationship Between Vehicle Based and Biomechanics Injury Metrics in Car-to-End Terminal Crashes using a Human Finite Element Model

Elijah Buckland, Costin Untaroiu

Department of Biomedical Engineering and Mechanics, Virginia Tech

Background/Objective:

In the United States, guardrail end terminal safety performance is assessed using crash tests. In order to calculate occupant injury risks from these tests, the current standard practice outlined in The Manual for Assessing Safety Hardware (MASH) is the flail-space model developed in the early 1980s. This model and other vehicle-based measures calculate injury using information such as velocity and acceleration. Since vehicle safety features have advanced over the years, there have been concerns over the validity of the flail-space model and other vehicle-based measures for accurately predicting occupant injury. In this study, finite element simulations of guardrail end terminal impacts were performed to investigate the relationship between several vehicle-based metrics and biomechanical injury measures using a human-body model.

Methods:

Using LS-DYNA, a full-scale crash simulation was created using a vehicle model (Toyota Yaris), an ET-Plus end terminal and the Global Human Body Model Consortium OS-50 (GHBMC OS-50). To test a range of initial impact conditions, 20 different simulations were performed including the combinations of five velocities, two offsets, and two impact angles. For each simulation, kinematic and kinetic data were recorded from both the GHBMC and the vehicle to calculate their respective injury measures. Then, using a logistic regression model, the correlation between the vehicle-based injury metrics and occupant injury probabilities was evaluated.

Results:

In total, 17 positive correlations were identified between vehicle-based metrics and occupant injury probabilities. The vehicle-based metrics were found to have a strong correlation with full-body injury probabilities. Additionally, OIVx, ASI, and THIV were shown to correlate well to chest, thigh, upper tibia, and lower tibia injuries while ORAx had strong correlation to neck injuries based on Nij. However, the correlations were not statistically significant for the remaining measures, particularly those used for head and brain injuries. This potentially indicates that vehicle-based measures cannot accurately predict injury outcomes for the head and brain.

Conclusion:

Overall, the results show that several vehicle-based metrics can accurately predict occupant injury and could be incorporated to increase the efficacy of end-terminal crash testing. However, head and brain injuries could not be predicted with the vehicle-based metrics and other test methodologies should be implemented if these injuries measures are needed, such as computational simulations as used in this study, or ATDs.