Development of a Hybrid-III to Human Leg Transfer Function for Axial Loading

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Abstract

The Hybrid-III anthropomorhpic test device (ATD) is commonly used for evaluation of human lower extremity injury risk in environments such as automotive intrusion and underbody blast (UBB), despite previous literature showing differences between the Hybrid-III and human lower leg mechanical response at faster loading rates. The non-biofidelity of the Hybrid-III legs poses a challenge for interpreting the large database of existing test data in relation to human response and injury risk. To solve this problem, transfer functions were developed relating tibia forces from both the Hybrid-III and post mortem human surrogates (PMHS) to axial impact data with loading rates ranging from 100 to 600 g's of peak acceleration with durations of 6.8 to 10 ms and impact velocities between 1.5 to 10 m/s.

Previously developed Hybrid-III and human lower limb finite element (FE) models were modified and validated for a range of axial loading rates using data from experimental ATD and PMHS drop tower tests. A parametric study using the two models simulated with the same impact conditions was performed, and upper tibia force response was compared between the models. A total of 15 triangular acceleration pulse impacts were used, varying in time to peak, duration, and peak accelertion. Transfer functions were developed to relate the proximal tibia force responses in each model to the impact conditions. Additionally, existing injury criteria were used to determine injury risk for the human based on the Hybrid-III force output.

Model results showed peak force and peak velocity in the Hybrid-III leg to be highly correlated (R2=0.98), while these quantities were less correlated in the human leg (R2=0.65). The human leg response was also dependent on the jerk of the impact, while the Hybrid-III model response was insensitive to this parameter. The developed transfer function relies on incorporation of loading rate to predict human response from a given Hybrid-III response. When assessed using existing injury criteria, the transfer function predicted a 50% human injury risk when the Hybrid-III axial upper tibia force was around 15.5 kN for an input of 600g's in 3.4ms, whereas a 6.4 kN force in the human leg corresponds to a 50% injury risk at similar rates.

The transfer function developed in this study is a first step to interpreting the large database of existing Hybrid-III leg data from UBB events to better assess the injury potential of the occupants in these types of events. Limitations of this work include the use of FE models to provide data for generating a robust transfer function, but this was deemed necessary in the absense of matched PMHS and Hybrid-III experimental data. The transfer function is only applicable for the range of impact conditions investigated, but these conditions are comparable to those measured on the vehicle floor during UBB tests. Future testing efforts will be necessary to fully validate the transfer function for a wider range of input conditions, and to verify that the injury criteria provides accurate injury prediction capabilities for the given loading rates.