Development of a Finite Element Model of the WIAMan Lower Extremity with a Comparison to the Hybrid-III Dummy and PMHS test data

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Abstract

Occupants of military vehicles are likely to be subjected to an underbody explosion resulting from anti-vehicular land mines and improvised explosive devices. During the recent war in Iraq, 26% of all reported combat injuries impacted the lower extremity. Therefore, there is an urgent need to introduce a series of new safety systems and regulations to mitigate lower limb injuries in theatre.

For years the automotive industry has successfully used human anthropomorphic testing devices (ATDs) to quantify the occupant injury risk over a wide range of impact scenarios. However, it has been proven that these ATDs are inadequate when it comes to accurately measuring the response of the human to blast loading. Therefore, a new dummy, called WIAMan (Warrior Injury Assessment Manikin) is under development, led by efforts from the United States Army Research Laboratory (USARL). The main objectives of this study were to validate the unbooted WIAMan lower limb FE model to begin investigating a human to dummy transfer function using the Global Human Body Models Consortium (GHBMC) lower limb. Preliminary effort to update the GHBMC lower limb FE model to be better suited for under-body blast simulations is presented.

A numerical model of the lower leg was developed for LS-DYNA by a multi-institutional research team. Material models in LS-DYNA were assigned based on high and low rate test data to replicate the complex behavior of the soft materials used to represent the flesh, calcaneus cap, foot plate and a tibia compliant element. The WIAMan FE model was simulated under identical conditions as the experiments done on the physical dummy. A comparison between the outputs from the simulation and the test data was used to validate the unbooted WIAMan-LX model. The GHBMC lower limb FE model was altered to improve the biofidelity of the model in response to accelerative loading. Preliminary comparison between the GHBMC model and post-mortem human surrogate (PMHS) testing is presented in this study.

The proposed numerical models of materials exhibiting viscoelastic responses show good correlation to the test data at both high and low strain rates. Simulations of the entire WIAMan-LX correlate well to the WIAMan physical dummy tests. One of the primary design criteria for the WIAMan-LX was improved biofidelity compared to existing models. Comparing the WIAMan and Hybrid-III lower extremity models to PMHS data shows the WIAMan to be more biofidelic. The updated GHBMC model responded with high similarity to the established PMHS corridors. The current study presents a partially validated model of a novel lower extremity ATD for investigating injuries caused by underbody blast events. Future work includes further validation of the model and the correlating the responses of the dummy to risk of human injury using an advanced numerical model of the human lower leg.