Injury Models

The WIAMan Project

The cornerstone of the DoD's effort to prevent mounted Service Members from receiving skeletal injuries when subjected to the effects of under-body blast is the WIAMan project. The WIAMan project is investigating human response and tolerance to vertical accelerative loads that can produce tertiary blast injuries, and is using that knowledge to create a scientifically valid test capability for evaluating the survivability of ground vehicles during research, development and acquisition. Led by the WIAMan Engineering Office of ARL, WIAMan was sponsored in 2010 by the Director for Operational Test and Evaluation (DOT&E) in the OSD to correct a shortcoming in the test technology used for Title 10 Live-Fire Test and Evaluation (LFT&E). The project is funded primarily by the Deputy Assistant Secretary of the Army for Research and Technology and by the Defense Health Program through the ASD(HA). DOT&E recognized a capability gap to assess skeletal injuries when mounted Soldiers are subjected to the rapid vertical acceleration that occurs when a vehicle is attacked by an under-body blast device such as an IED. ATDs are used to assess skeletal injury risk under such conditions. However the ATD currently in use, the Hybrid III, and the injury criteria used with it, were created for frontal automotive crash testing, and are inadequate for under-body blast conditions experienced by Service Members. To close this gap, the WIAMan project is conducting original biomechanics testing to characterize human response to vertical accelerative loading and to define human injury probability curves for skeletal injuries under these conditions. This information will be used to develop a new instrumented ATD that is purpose-built for use in the under-body blast LFT&E environment.

Biomechanics

Using theater injury data from the JTAPIC Program Management Office, and knowledge of the environment experienced by mounted Service Members, the WIAMan project is conducting a major biomechanics test program to gather required information on human response to underbody blast using post-mortem human surrogates (PMHS). Testing and analysis is being performed at nine of the top biomechanics universities in the United States: JHU/APL, Medical College of Wisconsin, University of Michigan Transportation Research Institute, Wayne State University, The Ohio State University, University of Virginia, Virginia Tech, Duke University, and Wake Forest University. These efforts are yielding the biomechanics knowledge needed to guide the design of the ATD and to create the injury assessment criteria that will be used with it. The test program considers factors and parameters of interest for understanding initial exposure to blast-induced loading including seating position and posture, the use of PPE, and severity of the loading environment.

The current WIAMan biomechanics focus is the development of biofidelity response corridors (BRCs) that are created by conducting sub-injurious testing with PMHS in order to evaluate and quantify biofidelity parameters, such as the time-dependent loading of the skeletal structure, and the resulting local and global deformation and kinematics. A BRC describes the distribution of biomechanic responses measured in PMHS. As of 2015, the WIAMan project has completed 14 BRC test series addressing the leg, lumbar spine, cervical spine, and pelvis regions, as well as the whole body. Six additional BRC series are currently in process. The BRCs will become performance requirements of the WIAMan ATD. When the ATD matches the relevant BRCs for a particular loading environment, it is considered to be biofidelic, a suitability requirement for making injury assessments. In addition to BRC tests, the project also conducted exploratory injury testing for the leg, pelvis, and cervical spine. The data are being used to validate that injuries produced in WIAMan testing match those experienced by Service Members in theater, and are also used to assess the validity of hypotheses that have been developed to guide the full human injury test program, which will begin in FY16. When possible, the new biomechanics information or capabilities will produce “spin outs” of knowledge that can be used to enhance the LFT&E injury assessment products prior to the fielding of the WIAMan system in FY21.

Instrumented ATD

In FY15, a technical data package for the WIAMan ATD concept was received through a contract with the Humanetics Innovative Solutions Corporation. Subsequently, a contract for fabrication of the first instrumented WIAMan ATDs was awarded to the Diversified Technical Systems (DTS) Incorporated, which will deliver the first WIAMan ATD technology demonstrator in December 2015. During FY15, DTS delivered parts of the ATD so component-level tests could be performed under the same conditions as PMHS testing (matched-pair testing). This testing provides data that can be used to evaluate biofidelity and refine the design and initial material selections. In addition, DTS has also been developing elements of the instrumentation and data acquisition system (DAS) that will be integrated with the ATD. The WIAMan ATD will use a distributed on-board DAS with a capability to acquire up to 148 channels of data. Load cells are being developed and acquired for use in the technology demonstrator ATD, and development of other elements of the instrumentation and DAS are progressing, including a six-degree-of-freedom accelerometer, the individual DAS units, and communication hubs.

Finite Element Analysis (FEA) Model

FEA is used to model the response and survivability of vehicles subjected to the effects of underbody blast, and an FEA description of the Hybrid III ATD is included in the simulation. However, the Hybrid III FEA model has limited validity for underbody blast loading conditions, and modelers make assessments of the risk of injury by applying the same injury criteria that have

been judged to be inadequate for use in physical testing. The WIAMan project will produce an FEA model of the ATD that can support virtual prototyping of vehicle survivability; the WIAMan FEA model will be correlated against test data and suitable for comparison with the injury assessment tools that the project is creating for use with the physical ATD. However, this high-resolution model is not only an end-product, but is also an important tool during the development of the WIAMan ATD. The WIAMan FEA model enables the study of design options and material effects in order to develop an ATD that meets biofidelity and strength-of-design requirements in the fewest possible fabrication iterations. In a joint FY15 effort among CORVID Inc, JHU/APL, Wake Forest University, and Virginia Tech, the project initiated an aggressive modeling effort and developed a baseline three-dimentional FEA model of the full WIAMan ATD that includes all sensors, and can be used in either the LS-DYNA or Velodyne solvers. As non-metallic materials were selected and fabricated, samples were tested and mechanical response models created which have been incorporated into the WIAMan FEA model. This 1.3 million element model is now in routine use for whole-body simulations, as well as simulation of component-level tests that are being performed for the cervical spine, lumbar spine, pelvis, and leg (including foot and ankle). FEA simulations have already provided extensive support to the project, enabling parametric sensitivity studies, strength-of-design studies for severe loading conditions, material optimization, and for pre-test predictions to guide physical testing of WIAMan ATD technology demonstrator hardware. Coordination meetings on the development of the WIAMan FEA model have been held with several DoD agencies, and several briefings on the effort will be presented at the 2nd Workshop on Accelerative Loading that will be held at ARL in January 2016.