Large-Scale Shock-Tube Testing for Coupled Blast and Fragmentation Modeling

Sean P. Cooper, Joe Crepeau, and Mohsen Sanai
Applied Research Associates
Albuquerque, New Mexico, United States

1 Abstract

Prediction of blast and explosion environments and their effects is essential to designing hardened infrastructure and minimizing loss of life during these events. In particular, at large scales, blast and fragmentation phenomenon occur on the same timescale, requiring full effects coupling for accurate predictions. Therefore, full- and sub-scale tests are required to develop and validate high-fidelity modeling and simulation (M&S) to understand phenomenology of these events and, therefore, to better predict their effects on existing infrastructure. To this end, the ARA Moriarty Range (AMR) is used to conduct both full- and sub-scale testing. Sub-scale tests mimic large-scale operation environments and provide data that can be used for M&S of full-scale events, thereby reducing the technical risks (test bed design, shot characteristics, instrumentation, etc.) of larger events to ensure high-quality data acquisition. AMR accommodates a Medium-Scale Shock Tube (MSST) and a Small-Scale Shock Tube (SSST) designed and built to test fundamental blast loading effects on materials, structures, and environment. The present work describes the MSST facility and discusses pressure data, high-speed video observations, and SHAMRC computer simulations of representative tests. Downstream pressure and synchronized high-speed imaging allow for characterization of the stagnation, static, and dynamic pressure environments, and three-dimensional particle tracking, respectively.

Being a compressed gas-driven shock tube, the MSST consists of two main sections a 4-ft-diameter, 81-ft-long driver section and an 8-ft diameter, 75-ft-long driven section. A ¼"-thick, steel diaphragm separates the driver from the driven section. A 4-ft-diameter moveable section allows for ease of diaphragm access and shape charge placement. An advanced pressurization system is used to remotely pressurize the driver section up to 500 psi. Linear shape charges are placed in a pin-wheel pattern to rupture the diaphragm into six petals to initiate shock propagation and produce external air blast overpressures up to 40 psi or positive phase durations of up to 150 ms, which is sufficient for testing full-scale walls and structures. The MSST is utilized as a risk reduction tool for high-cost field experiments and/or larger shock tube tests at sites such as the Large Blast and Thermal Simulator (LBTS).

Static and stagnation pressures are monitored along the inside of the shock tube and the concrete test floor, as well as in the free field using specially designed gauge stands to collect dynamic pressure in the blast environment. High-speed video cameras are utilized to capture stereoscopic images of fragments in flight. Utilizing ProAnalyst® image analysis software, these high-resolution images are used to obtain three-dimensional distributions of fragment size, velocity, and vector. Pressure and fragmentation data are then utilized to aid development of the high-fidelity codes. In particular, ARA utilizes the SHAMRC and Tether (fully-coupled SHAMRC and LS-DYNA) high-fidelity codes for predicting fragmentation and blast mechanics phenomenology necessary to accurately model events at these scales. Representative results from this ongoing testing and modeling effort will be presented.

Correspondence to: spcooper@ara.com