Abstract

In the recent past, with an increasing number of terrorist activities, blast related research has focused on conducting careful experiments to develop newer protection strategies. As field experiments using explosives themselves are very cumbersome and expensive, shock tubes are increasingly being employed to study these air-blast based phenomena as they can produce the instantaneous pressure rise that is associated with blast waves, minus the use of explosives. From the literature on shock tubes that are being used for blast loading, it was observed that no experiments have been reported in the sub-millisecond loading duration (near-field) regime as no extant facility has the capability to simulate the conditions in this regime. Even in reports on shock tubes being used to recreate far-field blast conditions (starting from _ 4 milliseconds), attention is not directed towards the shock tube experiment artefacts viz., repeated reflections inside the (closed) shock tube, and generation of a wave whose pressure remains steady for a time before dropping off like a blast wave. In this backdrop, shock tube experiments that pertain to the far-field conditions were first conducted and then quantified in terms of the equivalent TNT field explosion ('TNT equivalent' in short). The decay time was brought down to 1:6 ms by using plastic diaphragms, and an insert to channel out the reflected shock pressure. Then, the role played by the artefacts of shock tube loading on plates was shown to erroneously increase the final deformation of metal plates by about 15%. While the effect of these artefacts on the micro-structure did not show a large difference, the frequency content of both pressure loadings (the artefact and the correct one), showed differences in the spectral content, which could potentially change the response of structures that are sensitive to the frequency content of the input pulse. These shock tube experiments were found to have a repeatability of 5.5% and the plate deformation experiments on this facility were in the dynamic regime of structural loading. Using a more repeatable diaphragm less shock tube (1%), experiments were then conducted with similar decay times but on a smaller shock tube to validate the digital image correlation (DIC) technique. This device was then used along with numerical computations on ABAQUS to try and explain a blast mitigation strategy that gave a reduction in deflection of up to 50% in the quasi-static regime. To generate even shorter decay times, experiments using a piston impacting a water column were conducted. While the blast pulses from this facility could be reported in terms of their TNT equivalent mass, a subsequent correlation with the explosion-based plate deflection data failed as the exact impulse that is imparted to the plate could not be correctly determined. A novel conical shock tube that can generate sub-millisecond decay times (the near field conditions) in air was then developed and experiments on different metal plates (mild steel, aluminium, copper) were conducted for the extreme case of structural loading, viz., impulsive loading. The plate deflection data from this facility compared very well with an empirical formula that is available for impulse loading of plates using explosives. Thus, the ability of this device to reproduce several features of a near-field air-blast loading - namely the elastic spring back, the impulsive loading of a plate, and a unique shape of the deformed plates - were all successfully demonstrated. The device was characterized at reduced pressures to have a repeatability of 5% and the spatial variation in the exit plane pressure was better than 7%. Using this device, a scaled equivalent of a possible explosion from an improvised explosive device (IED) was also administered to mice to explore the possibility of ultimately conducting controlled blast induced traumatic brain injury studies in the laboratory. Over the course of this work, the simulation capability of shock tubes over an extended range of air-blasts was demonstrated. In terms of TNT masses and stand-off distance, it is currently as follows: Far and mid-field range - using the

diaphragm less shock tube (49 kg@5:3m –25 kg@8:4m), and using the vertical shock tube from (0:31 kg@0:86m–33 kg@6:4m); Near-field range: water shock tube (2 kg@0:63m) and the conical shock tube (0:04 kg@0:38m– 0:08 kg@0:56m).