SIMULATION OF A CAPSULE SUBJECTED TO AN UNDER BODY BLAST

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During an Under Body Blast (UBB), the seated occupants are significantly accelerated, primarily through the floor and seats, which may lead to severe injuries and fatalities[1,2].
Numerous studies have captured the injury severity and lethality of mounted victims due to an UBB[3,4,5,6]. Studying the mechanisms of these injuries are expensive and inimitable with experimental blasts, as each full-scale blast experiment have too many variables. The development of a numerical model could reduce costs and limit variables to better define mechanism of injury.

Introduction: Improvised explosive devices (IEDs) and Landmines, are regularly used to subject military vehicles to Under Body Blasts (UBBs), resulting in significant accelerations being transferred through the seat and the floor to the occupants[1,2].
The accelerations on the occupant may lead to injuries and fractures of the occupant's lower extremities, pelvis and spine[2].
As pelvic and spine fractures are associated with high mortality rates and are often debilitating, resulting in increased healthcare expenses and a reduced quality of life[3], there is a critical need to understand and mitigate the respective mechanisms of injuries.
Various studies have captured the injury severity and lethality of mounted blast related injuries, with possible concepts of injury mechanisms[3,4,5,6], but there is currently no objective test methodology to determine the transmission of forces, nor the risk of injury to the pelvis, due to the vertical translations of the seat. Studying the mechanisms of these injuries are expensive and inimitable with experimental blasts, as each full scale blast experiment have too many variables.
As the z-axis accelerations and forces are usually the most significant during an UBB event, limiting global movement of a test capsule in this direction already eliminates a few variables. Various full scale z-axis testing capsules have been developed for this purpose of which one is the CSIR HRTR, illustrated in Figure 1.

Figure 1: CSIR Human Response Test Rig

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The development of a numerical model of the CSIR HRTR could reduce costs and limit variables to better define mechanism of injury from the seat to the occupant. The aim of this paper is to presents a simplified blast capsule, based on the geometry of the CSIR Human Response Test Rig (HRTR), modelled in LS Dyna, subjected to an underbody blast. The purpose of the model will ultimately be to study the load transfer from the seats onto the pelvis and spine of the occupant during an UBB. The paper present the numerical setup, structural acceleration results and provide recommendations for future improvements and validation of the model.

Model descriptions: A half symmetric blast capsule subjected to a 6kg flush buried charge and a Stand of Distance (SOD) of 500 mm was modelled. A Multi-Material Arbitrary-Lagrangian-Eulerian (MM-ALE) Fluid Structure Interaction (FSI) approached was followed using LS-PrePost v4.5.14. The model consisted of three keyword files, the Air and soil, the Capsule and the combined FSI model as illustrated in Figure 2.

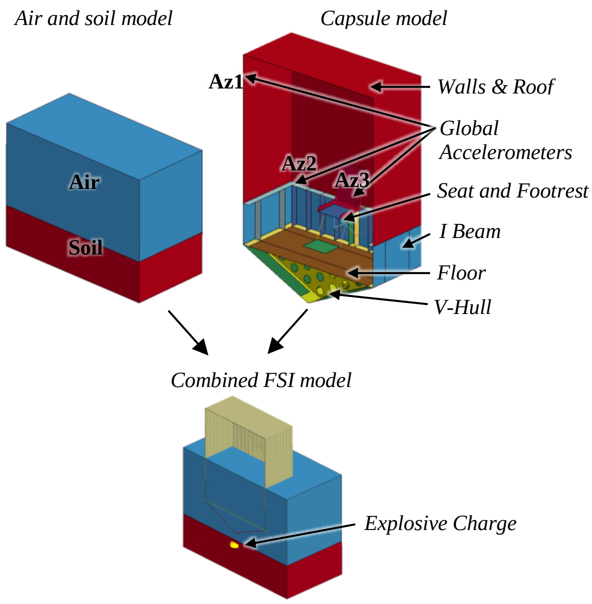

Figure 2: Models description

The first keyword file contained the air and soil properties, consisting of two parts with 50 mm^2 solid element size and a total of 192000 elements.
The second file contained the capsule properties with a total of 11765 shell elements. The capsule has a V-hull

at the bottom, followed by a floor and structure, all with element sizes of 50 mm^2. A seat and footrest, element sizes of 20mm^2, were connected to the back wall with square tubing defined as beams.

The third file made use of the *INCLUDE and *INCLUDE_TRANSFORM keywords to include the first two models into a FSI model. The FSI model consisted of several keywords for defining the boundaries, the constraints, the detonation, the Volume Fraction Geometries (VFG) and all the control and database keyword cards.

A global constrained was set to only allow movement in the Z axis and restrict movement in the X and Y axis. A *CONSTRAINED_LAGRANGE_IN_SOLID keyword card was created with the slave set as the V-hull, floor and capsule and the master as the air and soil. Five *ALE_MULTI-MATERIAL_GROUPS were created, one for the soil, the air outside, the explosive and two for the air inside the v-hull and the capsule. The *INITIAL_VOLUME FRACTION_GEOMETRY keyword card was used to define 5 volume geometries for each of the multi material groups. The model was terminated after 5 ms, with increments of 0.1 ms and a time step scale factor of 0.6.

Results: The sequential images of the blast propagation interaction with the capsule are presented from 0 to 2.5 ms in 1 ms intervals in Figure 3.

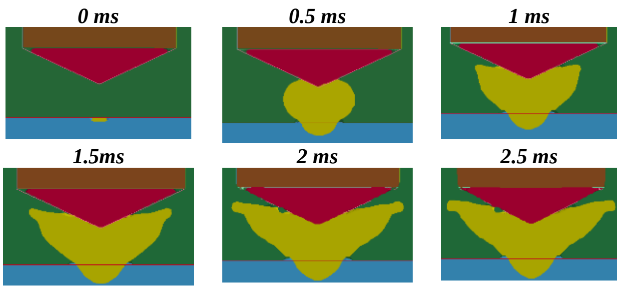

Figure 3: Blast and capsule FSI interaction

The global structural accelerations of the seat, corners and top of the structure are shown for the first 5 ms in Figure 4.

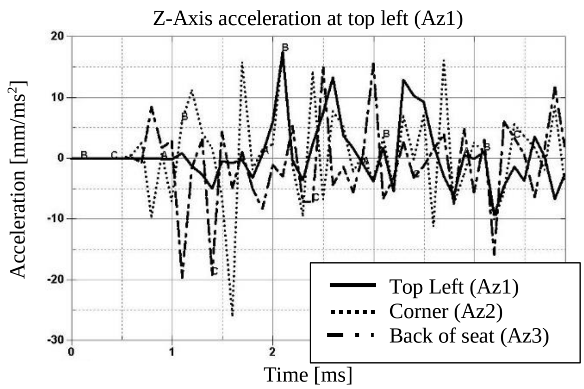

Figure 4: Global accelerations of LS Dyna Model

Conclusion: A Under Body Blast (UBB) on a blast capsule, restricted to z-axis movement, based on the CSIR HRTR dimensions, was presented. The global acceleration peaks of the structure showed good correlation to experimental results of similar charge size and SOD, however time to peak did not compare. With refinement, the model can be used for future research on defining injury mechanisms from the seat to the occupant during an UBB event.

Recommendations: It is recommended that the model should be compared to structural experimental results of the CSIR HRTR. Further recommendations are the inclusion and refinement of internal structures like the structural beams, improved material models, as well as the inclusion of Anthropomorphic Test Devices (ATDs) coupling. In order to study both the structural deformations of the HRTR and the occupant responses simultaneously, MADYMO-LS-Dyna coupled simulation is recommended.

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