

Vehicle and Occupant Safety Protection CAE Simulation

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ABSTRACT

The objective of this research is to investigate the effect of the blast load on the vehicle and occupant and identify the sensitivity of the vehicle parameters to the blast load, therefore figure out the design solution to protect the vehicle and occupant. CAE explicit commercial code, LSDYNA, is applied in this research with adopting CONWEP method for the blast load. The LSDYNA 95th percentile Hybrid III dummy model is used for occupant simulation. Seat, seat belt, and underbody and underbody armor are interested areas in the design to meet the survivability and weight target. The results show the protection can be effectively achieved through employing the new design method in three areas mentioned above.

INTRODUCTION

Many Army ground vehicles aim to improve the crew survivability when engaged by mine or Improvised Explosive Device (IED). Those underbody blast threats posed a high risk to a vehicle and its crew. Energy absorbed seat, increased ground clearance, a V-shaped underbody and armor cooperate to reduce acceleration effects to the crew.

Brill et al. [1] and Williams et al. [2][3] demonstrate their study with various simulation methods to the vehicle and occupant. Tabiei et al. [4] showed their method to reduce the impulse to the occupant through energy absorbing seat.

The objective of this study focuses on how the design of the seat and underbody armor will improve the vehicle survivability. A commercial SUV FE model, downloaded from internet, is used as an example vehicle. The human occupant is simulated by a 95th percentile Hybrid III dummy. Data like head and torso acceleration and feet velocity of

crew are collected during the simulation and for the injury assessment.

BLAST LOAD METHODOLOGY

Today, two approaches are available: one can either use an ALE model (*ALE) with a Lagrangian-Eulerian coupling (*CONSTRAINED_LAGRANGE_IN_SOLID) or a pure Lagrangian approach (CONVEP method) in LS-DYNA (*LOAD_BLAST) where an analytical loading of the structure replaces the computation of the propagation [5].

AIR BLAST PHENOMENA-GENERALITY

When a high explosive detonates, a pressure front propagates into surrounding atmosphere. This strong incident shock, called the blast wave, is characterized by an instantaneous increase from ambient pressure to peak incident pressure. Generally this shock is characterized by use of a Friedlander formulation (positive phase) [6]:

$$P_s(t) = P_{so} \cdot \left(1 - \frac{t - t_A}{t_0}\right) \cdot \exp\left(-\beta \frac{t - t_A}{t_0}\right) \quad (1)$$

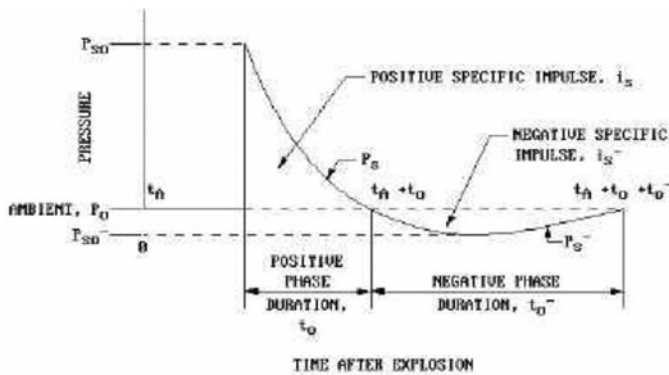


Figure 1. Pressure-time evolution (Courtesy from Reference [5])

Air blasts phenomena can be separated into three categories: Free air burst, Ground reflection effects and Surface air burst.

Free Air Burst

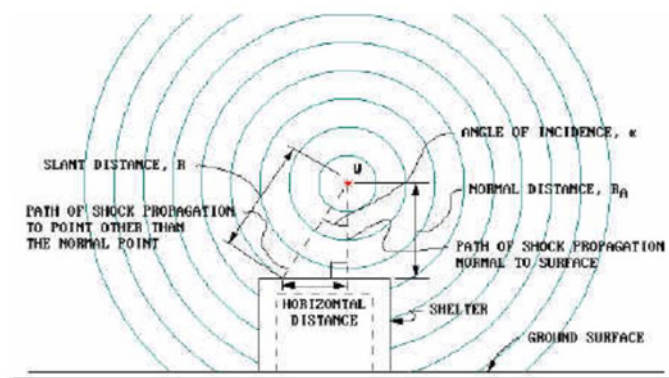


Figure 2. Free Airburst Configuration (Courtesy from Reference [5])

Ground Reflection

It is necessary to take in account the ground effect when the incident wave is reinforced by it. Two phenomena can occur: either a classical reflection or a Mach Front reinforcement reflection.

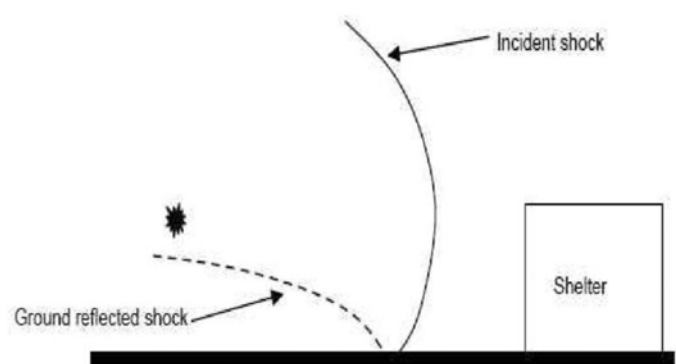


Figure 3. Ground Reflection Configuration-Classical (Courtesy from Reference [5])

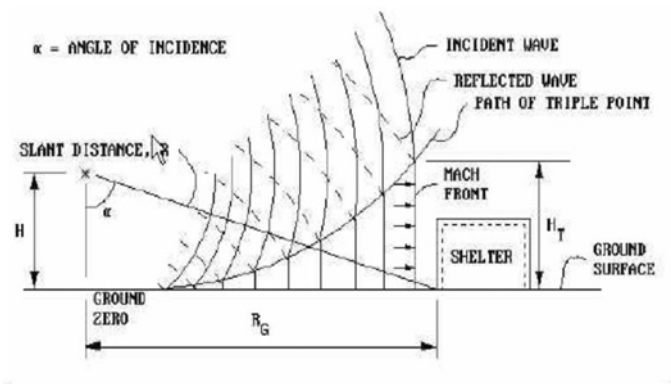


Figure 4. Ground Reflection Configuration-Mach Front (Courtesy from Reference [5])

The Mach Front is formed by the interaction between incident and reflected pressure waves. This interaction depends on the angle of incidence between ground and incident waves. The critical angle is of around 40° . The pressure-time variation of the Mach front is similar to that of the incident wave except that the magnitude is somewhat larger.

Surface Burst

Surface airburst occurs when the charge detonation takes place close or on the ground. Unlike what happens in an air burst, the incident and reflected wave are merge near the detonation point to form a single reinforced wave. The created wave is hemispherical.

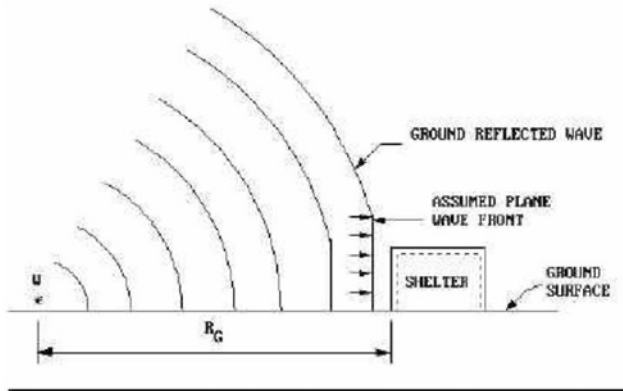


Figure 5. Surface Burst Configuration (Courtesy from Reference [5])

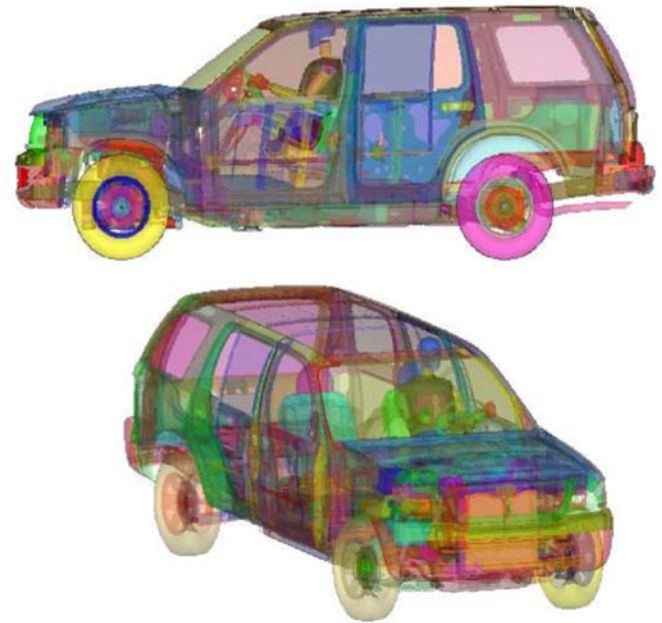


Figure 6. Sample FEA Model in the Analysis

Airblast Empirical Models

Empirical model that enable the computation of the structure blast loading are based on abacuses which are themselves functions of the scaled distance Z :

$$Z = \frac{D}{\sqrt[3]{W}} \quad (2)$$

where D is the distance to the charge and W is the charge's mass

INJURY ASSESMENT

Due to the overpressure of the blast load from mine and substantial shock acceleration transferred to the occupant, a vehicle system can be damaged which therefore causes crew's injury [2][7].

Table 1 gives the injury criteria. The injury criteria used for the head and pelvis were developed using the Hybrid III ATD (Alem, 1996) [8]. For the feet, the criteria is based on experimentation with cadavers (Black et al., 1945 and Draeger et al., 1945) [9].

Table 1. Injury Criterion

Part	Injury Criteria
Head	$a = 150 \text{ g}$ for 2 ms High risk of brain damage
Pelvis	$a = 40 \text{ g}$ for 7 ms High risk of spinal cord damage
Feet	$v = 3.5 \text{ to } 5.0 \text{ m/s}$ Apparition of lower leg fracture

COMPUTATIONAL MODEL

A commercial vehicle, as shown in Figure 6, is used as a sample computational model to do the analysis. A LSDYNA 95th percentile Hybrid III dummy model is fixed on the seat by three point seat belt.

UNDERBODY ARMOR DESIGN

A regular vehicle is blasted with 2 kg TNT [7] directly under the driver seat on the ground, which is regarded as the most severe position to the occupant. The underbody floor pan is severely damaged as shown in Figure 8, and therefore the driver is deadly injured which can be seen in Figure 9 that the spinal is out of the body.

<figure 7 here>

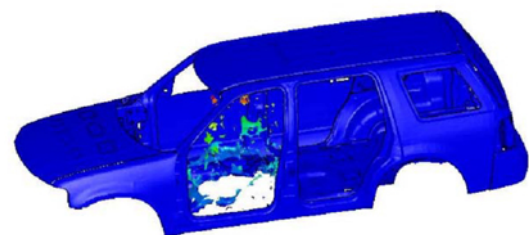


Figure 8. Floor Pan Severely Damaged