Mine explosion and blast effect on vehicle analysis of the potential damages on passengers

2nd European HyperWorks Technology Conference

Strasbourg September 30th – October 1st, 2008

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All over the world, guerrilla methods are more and more used.

Today, terrorist attacks can affect both military and civilian vehicles.

For these specific applications, numerical simulations can be useful to estimate damages created by a mine explosion, and to improve survivability of occupants.
Numerical Simulation of a mine explosion under a civil vehicle

Explosion of a buried landmine of 6 Kg of TNT under the front wheel of a civil pick up

The RADIOSS model takes into account:

– Arbitrary Lagrange Euler (ALE) method for Fluid and Explosive [JWL] Modeling

– Fluid Structure Interaction (FSI) between vehicle and blast wave (interface type 18)

– Deformable Structure of vehicle

– HYBRID III dummies to estimate damages caused by the blast wave

Landmine 6kg of TNT
Problems raised by this kind of applications

Distortions and deletions of the structure during exploding solicitation ➞ Impossibility to manage a fluid mesh coincident to the structure mesh.

Interest of the Fluid Structure Interaction (FSI)

interface TYPE 18:
• Lagrangian structure and Eulerian fluid meshes are not linked

Inherent difficulties due to the interface TYPE 18
• Determination of the good stiffness of interface
• Required finely of fluid mesh to get a good precision in the FSI
Previous studies have showed that the relation below can be used to estimate the interface stiffness.

\[ K = \frac{\rho \cdot c^2 \cdot S}{\text{Gap}} \]

- \( \rho \): Fluid density
- \( C \): wave celerity
- \( S \): Shell Section of the structure parts
- \( \text{Gap} \): interface gap

This equation permits:

- To be freed from an analysis of sensitivity at each new study
- To have a good evaluation of every studied cases
Explosive part and AIR volume around vehicle are meshed with BRICK elements.

Fluid Parts are set up with Arbitrary Lagrange Euler (ALE) formulation

Air is modeled as a perfect gas by Mie Gruneisen hydrodynamic law, where pressure is given by the equation of state:

\[ P = C_0 + C_1 \mu + C_2 \mu^2 + C_3 \mu^3 + (C_4 + C_5 \mu)E \]

With

\[ \gamma = 1.4 : \mu = \frac{\rho}{\rho_0} - 1 \]
\[ C_0 = 0 \]
\[ C_1 = C_2 = C_3 = 0 \]
\[ C_4 = C_5 = (\gamma - 1) = 0.4 \]
\[ E_0 = 0.25 \]
The mine shape has been defined as described in the “AEP-55 NATO/PfP UNCLASSIFIED / Procedures for evaluating the protection level of logistic and light armored vehicles”

The mine is modeled by a cylinder with an equivalent mass of TNT (6 Kg).

The TNT behavior is managed by Jones Wilkins Lee material Law [JWL] in which the Equation Of State of Pressure is calculated by the following equation:

\[
P = A \times (1 - \frac{\omega}{R_1} \times V) \times e^{-R_1 \times V} + B \times (1 - \frac{\omega}{R_2} \times V) \times e^{-R_2 \times V} + \frac{\omega \times E}{V}
\]
Pressure wave and celerity of the blast are correlated with TM 5 – 1300 “Structures to resist the effects of accidental explosions”

Blast wave shape in free field

Calculation of the Reduce distance

\[ R \text{ (m.kg}^{-1/3}\text{)} \]
Blast simulation of the mine in semi free field
An Hybrid III dummy is set on seat to simulate driver behavior and to estimate body damages.

The 50th percentile ATD represents the average male of population between 1970s and 1980s with the following figures:

- length (standing position): 1.72 m
- weight: 78 kg
- erect sitting height: 0.88 m
Mine explosion Simulation

Damages caused by the mine explosion under front wheel

[6 Kg of TNT]
Blast effect on the front part of the car structure.
Blast effect on the front part of the car structure.
Damages caused by the mine explosion: a hole is created in the under structure parts by the blast ➔ The blast penetrates in the vehicle

Important structural damages are noticed on the lower parts of the vehicle

In the firsts millisecond of the explosion, Legs are broken
To estimate damages on driver body, the AEP-55 NATO can be used. For examples, Pelvis acceleration or contact forces between feet and under structure can be plotted.

Lower Tibia Load Cell

In this case tolerance value of 5.4 kN is reached at 3 ms.
Mine explosion Simulation

Pressure measured at the head level of dummy

Pressure time history in vehicle

Sound level above 140 dB

Pressure level MPa

Time in ms

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In case of important damages, simulation can be used to design and test shield to reinforce vehicle structure ➔ Armor plates can be added under vehicle to avoid blast penetration in car.

Here, a plane steel armor plate is tested:

**Rigid vehicle**

**Steel Armor plate**

**Cylindrical mine (6 Kg of TNT)**

A quarter of FE Model is used for simulation.
Protection design

Pressure level on steel armor plate.

Mine: 6 Kg of TNT
In case of important acceleration level on passenger, energy absorbers can be mounted under seat to limit acceleration peak.
This methodology is adapted to study that kind of phenomena or cases where blast is generated by an explosion far from vehicle.

Sensitivity studies can be easily performed to improve vehicle design or to prepare a tests campaign.

This methodology can be applied to other explosion cases:

- Explosion of hydrogen tank to evaluate damages on persons around detonation point
- Luggage explosion in plane or train