# P04703 Crash Impact Modelling - Modelling Report Marking Scheme

## Marking Scheme

| | Mark Distribution | Alphanumeric Grade |
|---|---|---|
| Introduction | 0% | N/A |
| Presentation | 4% | A* |
| Procedure | 4% | A* |
| Results | 9% | B+ |
| Discussion | 9% | A |
| Effort and Innovation | 5% | A** |

## Comments

- Presentation

  The report is quite well laid out. It is easy to understand and the layout seems to be the best way to present this sort of work while also keeping up with the word and page limit.

- Procedure

  Procedure is explained nicely with justifications and proof for every decision provided. Method used is supported with sufficient evidence and the approach is perceived to be correct.

- Results

  Could not achieve the results expected. Not accurate at all. However proper justification for each incorrect result is given.

- Discussion

  A comparatively concise discussion section. However, the errors are identified and mentioned. The probability of each error occurring is adjudged properly.

- Effort and Innovation

  The project was taken on with good attitude and clearly has novelty. The author takes on the challenging task of FSI along with limited information on boundary conditions.

# IED (Improvised Explosive Device) Blast Impact Simulation on underbody of AFVs (Armoured Fighting Vehicles)

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## Introduction and Literature Review

Since the inception of basic armour, Human instincts to protect self from harm has been proved through history. An IED (Improvised Explosive Device) is an explosive device used as a counter mobility device to nullify the threat of an AFV. AFV providing the ability to employ manoeuvre, firepower and shock action, therefore becomes a very useful mobility machine. Because of presence of these devices it is important to use appropriate testing.

Military applications of LS-Dyna could be immensely helpful. Various types of blast simulations are carried out to predict the damage caused. A simple underbody of AFV is modelled and meshed in CATIA. The blast wave transferred to the passenger compartment has the ability to impart fatal acceleration to occupants and vehicle structure deforming force. Simulations carried out would be compared with real-time blast testing data for validation. Further work involves increasing the complexity of the model. Overpressure distribution, vertical displacement, velocity and acceleration are studied in this paper. Simulated results are compared with actual tested data of the same material under similar circumstances and suitable comments are drawn.

# Computational Modelling

## Geometrical Modelling

US army TARDEC has developed a generic V-Hull structure, whose 1DoF model is used in this study as baseline numeric model. The material and the mass properties of the V-Hull could not be obtained for the same V-Hull as it is still in use by the US army. Therefore, an alternate result-based approach is used for this study, wherein real-time blast testing data for certain materials is analysed.

V-Hull is modelled in CATIA and is kept to be a very basic model on purpose, so as to obtain just the underbody analysis. This also helps in corelating the simulation data with the real-time data, as the real time data is conducted on flat sheet of the material used in V-hull. IED and the Air volume is also modelled in Catia.

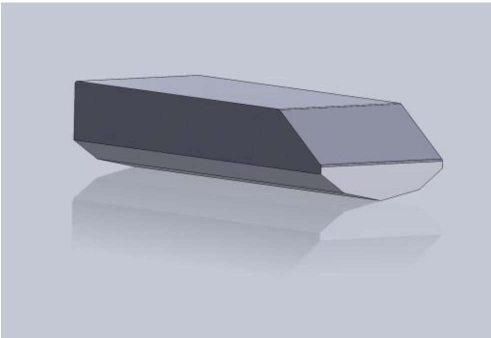


*Figure 1: V-Hull Solidworks Model*

The dimensions of the V-Hull, IED and the Air Volume is given below in table 1. IED is modelled as a cylinder and the air volume is taken to be a huge cuboid covering the V-hull and the IED.

| Dimensions (mm) | | | | |
|---|---|---|---|---|
| | l | b | h | radius |
| V-Hull | 6096 | 2130 | 1500 | - |
| IED | 500 | - | - | 571 |
| Air Volume | 9011 | 3000 | 5014 | - |

*Table 1: Component Dimensions*

## Mesh Details

Numerical modelling for predicting events such as blast is always challenging. It is particularly challenging to create a correlation between simulated and experimental results as it is not necessary that all the physics has been included in the model, viz. Thermal Effects, etc. therefore there are certain procedures in model development to aid in obtaining better results.

It was important, therefore, to have a refined mesh. The mesh refinement may not help in convergence with the eventual experimental result because of missing physics.

Design software CATIA is used for meshing purposes. While the V-Hull is a surface mesh as it is supposed to behave as a shell in LS-DYNA, the IED and the Air Volume are both Volume meshes, as they are supposed to be 'solid' elements in LS-DYNA.

A fine mesh is sored after for better convergence. The V-Hull has 10mm linear surface mesh across all its faces and edges. The IED has 8mm surface mesh, with tetrahedron filler of size progression 1 making it a volume mesh. For the Air volume, a surface mesh of 15mm size is opted for along with sweep 3D function. The volume mesh of air accounts for the V-Hull and the IED present inside of it and does not affect the mesh or the surfaces of V-Hull and the IED.

# Methodologies and Simulation Details

LS-DYNA offers a range of solution strategies to a particular problem and a knowledgeable user would take advantage of this. However, since this is a time-bound project, there is no alternative but to follow only one solution strategy which suits the best for the purpose of this study.

Len Schwer ET. Al. compared different blast techniques comparing their advantages and disadvantages against experimental data. It is found that each of the strategies has its own disadvantages, FSI with ALE model is chosen for this study.

To overcome the challenges faced during blast simulation and also to get acquainted with LS-DYNA, a step-by-step methodical approach is laid out and followed. The V-Hull and the Air is first simulated together. The V-Hull is given an INITIAL_VELOCITY and from the simulation it is derived whether the V-Hull is interacting with Air. The next step was to model IED and the Air and checked for IED interaction with Air. Once both these simulations are run, the final simulation of V-Hull, IED and the Air together is run.

However, there was a problem with the IED not interacting with the V-Hull, giving no output. On further research it was found that a constraint between the solid elements and the shell elements had to be created. The methodology used for this study had problem as there was too many simulations to be run to perfect each step, without which the final simulation would not have run. However, it was useful in getting acquainted with the software, allowing to focus on the details.

## Materials Model

The materials for each of the component in the simulation is taken from research and literature review. DRDO (Defence Research and Development Organization) in India were kind enough to state the materials that are generally used in V-Hull. They could not release any test data, however, as it is a confidential matter held by the Country.

The material properties used in this study is taken from research done in the initial stages and it was also found that to conduct such an experiment Equation of State also had to be defined for certain components. V-Hull's material is very important in this study and is chosen to be RHA steel which is essentially Aluminium 3-series H-14. Experimental data for this material with blast conducted on a plate is also found to help with the correlation of simulated and experimental data. All the units used for conducting the experiment is SI.

```
*MAT_PLASTIC_KINEMATIC_TITLE
V_HULL_MAT
         2    2730.0    6.89E9      0.33  145000.0 5000000.0       0.0
       0.0       0.0       0.0       0.0
```

*Figure 2: V-Hull Material Property*

PLASTIC-KINEMATIC material is chosen as the base model upon which the supporting values are fed in to obtain the Aluminium 3 series material desired.

```
*MAT_HIGH_EXPLOSIVE_BURN_TITLE
IED_MAT
         1    1770.0     8.3E9   3.35E10       0.0       0.0       0.0       0.0

*EOS_JWL_TITLE
IED_EOS
         1   6.17E11 1.6926E10       4.4       1.2      0.25   1.01E10       1.0
```

*Figure 3: IED Material and EOS property*

IED material is HIGH_EXPLOSIVE_BURN. PEN is an explosive material which is modelled as IED material in this study. The PETN parameters for the Jones-Wilkins-Lee EOS were obtained from the LLNL explosive Handbook.

```
*MAT_NULL_TITLE
AIR_MAT
         3      1.29       0.0       0.0       0.0       0.0       0.0       0.0

*EOS_LINEAR_POLYNOMIAL_TITLE
AIR_EOS
         2       0.0       0.0       0.0       0.0       0.4       0.4       0.0
  250000.0       1.0
```

*Figure 4: Air Material and EOS Property*

Air surrounding the V-Hull is modelled as a null material with EOS_LINEAR_POLYNOMIAL behaving like an ideal gas with an initial pressure of one atm.

## Simulation Details and Boundary Conditions

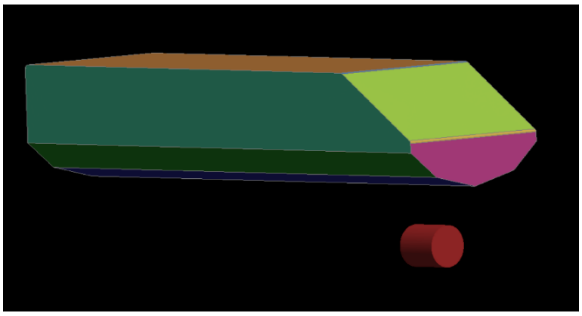


*Figure 5: Model Import in LS-DYNA (Air Hidden)*

The V-Hull was modelled using shell elements, ELFORM=2 Belitschko Tsay with four through thickness integration points. Engineering model LOAD_BLAST_ENHANCED is used for conducting free air blasts from curved TNT surfaces. LOAD_BLAST_ENHANCED is used in this study to define the model for blast impact. *CONSTRAINT_LANGRANGE_IN_SOLID is used to define the relation between solid and the shell elements in the model, hence between Air & V-Hull and the IED & V-Hull. This was figured out after multiple failed simulations providing no results. Relation between IED and Air is defined using LS-DYNA's CONTACT_AUTOMATIC_SURFACE_TO_SURFACE. It is derived that, the uncertainty and lack of data in defining the surface to surface contact has led to the unrealistic and inconsistent results obtained. This will be further discussed in the later sections. The model is simulated for 10 ms.

```
*TITLE
IED + V_HULL + AIR_VOLUME
$
$
$
$ =============
$ CONTROL cards
$ =============
$
*CONTROL_ENERGY
         2         1         2         2
*CONTROL_TERMINATION
    1.0E-4         0       0.0       0.0       0.0         0
$
$
$ ==============
$ DATABASE cards
$ ==============
$
*DATABASE_GLSTAT
    1.0E-5         0         0         0
*DATABASE_BINARY_D3PLOT
    1.0E-5         0         0         0         0
*DATABASE_FSI
    1.0E-4
         1         4         0         0         0
```

*Figure 6: Boundary Conditions*

## Result and Discussion

Blast simulation is a massive undertaking in itself and the author has tried to complete the project successfully. Experimental data of the blast with similar boundary conditions having same IED distance from the plate is during literature review. The aim of the project was to study overpressure, displacement, velocity and acceleration parameters on the RHA plate used as V-Hull underbody. The experimental data is shown below.

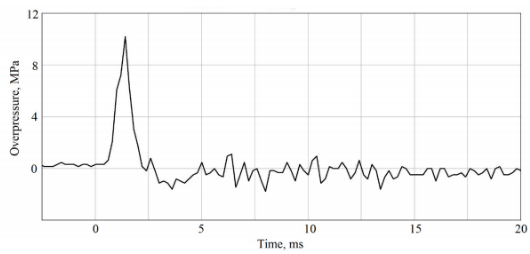



*Figure 8: Overpressure distribution on the RHA Plate*

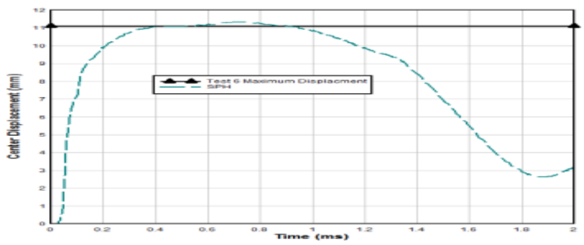



*Figure 9: Displacement Distribution*

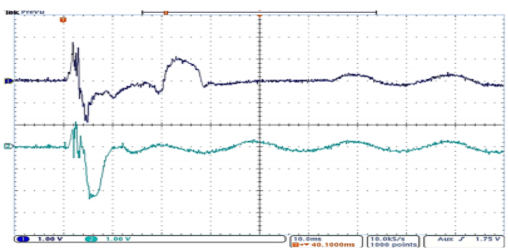


*Figure 7: Velocity Distribution*

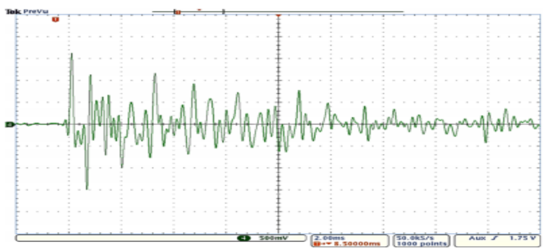
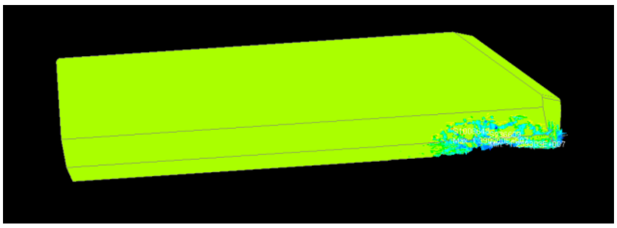
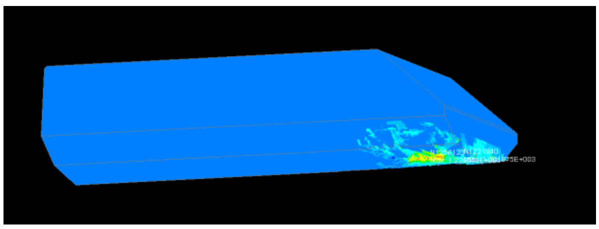


*Figure 10: Acceleration Distribution*

The project is not completed successfully. The simulated results could not be correlated with the experimental data shown above. This is attributed to not having full physics in the model or having faulty boundary conditions. The simulations do show a graphical result which seems to be correct. The author has tried his best to obtain the right plots. It is also found that the results obtained are inconsistent, every other simulation gives different graphs and a single node graph could not be obtained due to system crashing. *DATABASE is altered in hope to resolve this issue.





Simulation results are shown below in graphical format for the said parameters.

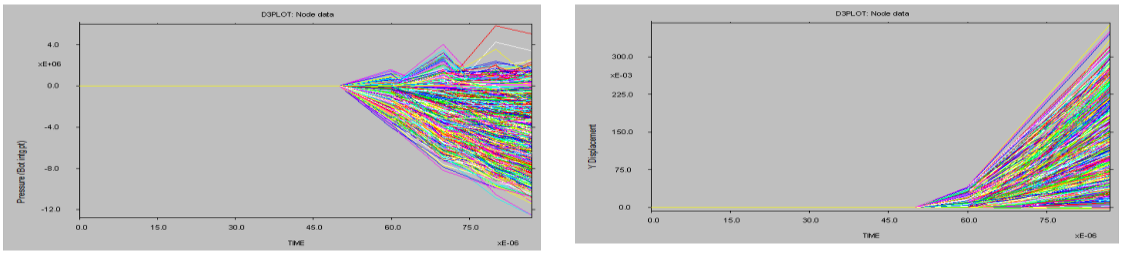



*Figure 12: Overpressure and Displacement Distr. (simulated Data)*

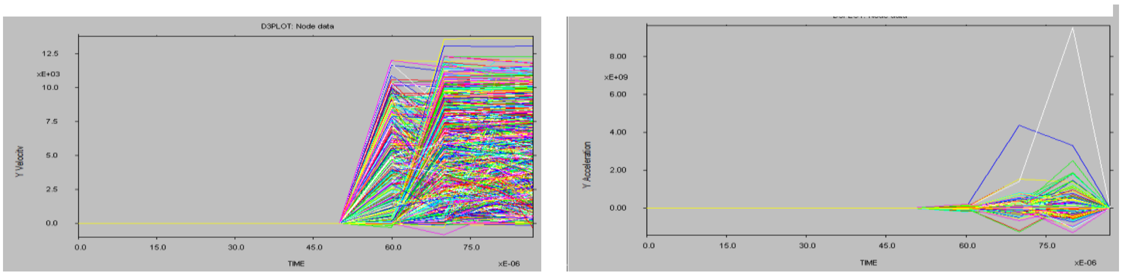



*Figure 11: Velocity and Acceleration Distribution (simulated Data)*

It is evident that the simulation results are not as expected. The author also tried to change mesh settings but that didn't make any difference at all.

## Summary, Conclusion and Future Work

The project is concluded to be unsuccessful. This could be rectified with more time and industrial help. It is also noted that the boundary conditions are not put out well. Since it is military based project, obtaining accurate data is not possible and it would be helpful to work with defence research organisations and relevant industry to make it a successful study.

Even though the results obtained were unexpected, it was a great learning experience. The author is now confident of approaching complex LS-DYNA problems in the future.

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