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Optimization of Hull Structure of an off-road vehicle to reduce Mine Blast Impact

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ABSTRACT

Armoured vehicles generally come in contact with mine explosions. The hull floor of armoured vehicles is usually made up of a plate having a few millimetres thickness and hence it is a weak vehicle point in the case of blast explosion. Therefore, blast resistance and the possibility of blast loads redirection are very important characteristics of Armoured vehicles in providing safe and high protection. It is generally accepted that Armoured vehicles with shaped floors are more resistant to mine explosions, yet there is absence of strong evidence of their blast protection mechanisms. This paper presents the results comparisons for 4×4 Armoured vehicles with a flat hull floor and its modified V-hull floor with a 90° angle considering the protection level of the standard. For that purpose, combined Smooth Particle Hydrodynamics (SPH) – Finite Element models were used. The results have shown that the V-hull floor offers a best improved vehicle response to blast loads. Blast waves are effectively dispersed and the local response of the vehicle also improved, which is very important while designing safe Armoured vehicles as required by standard safety rules and their requirements.

Keywords-V-Shaped Hull, Mine explosion, soldier safety, Blast impact

1. INTRODUCTION

For increasing the safety of military vehicle crews, Different protective methods can be used. It includes simple improvements applied directly on the battle fields or combinations of more advanced Armoured vehicles designs and protective materials. A Light Armoured vehicles hull floor design that provides sufficient protection gives a serious challenge. The effect of mine blast loads, in combination with the structural geometry and mechanical properties of the materials involved can cause vehicle damage, crew injuries and also sometimes death. Hence, it is necessary to study and improve the response of Armoured vehicles to these high-intensity loads.

There are Different hull floor shape designs were invented in the past for improving the vehicle response to blast loading. Performance of blast loading experiments involving real armoured vehicles is highly expensive and time consuming. It requires a large number of experts from different fields and many permits and extra safety requirements which are to be completed before testing of the vehicle. For this reason, the research is mainly focused on studying simple plate structures which armoured vehicles hull floors are made of. Comparison analyses between Different shapes are studied in this topic.

There are different shapes of Hull are used in defence vehicles Case 1) ***Flat Hull Floor***

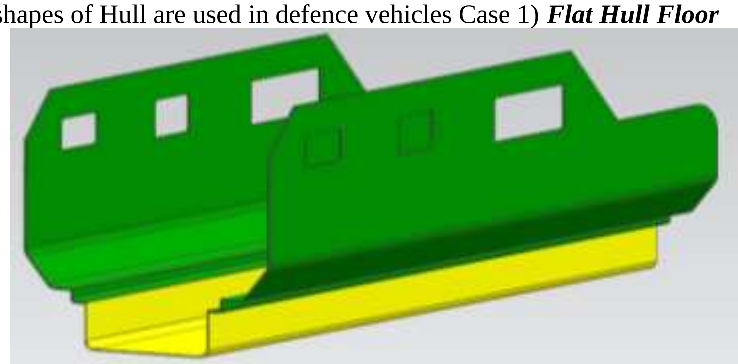
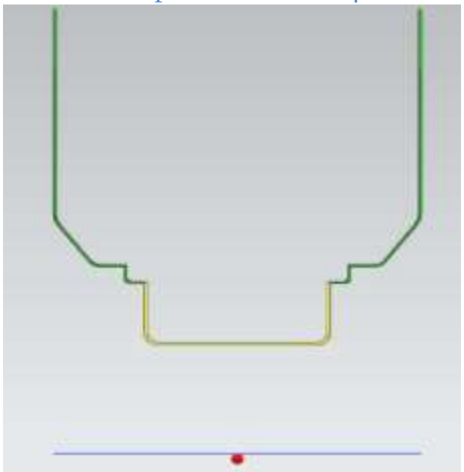


Fig. Armoured vehicle with flat Hull floor

- In this type of hull bottom portion of vehicle is fully flatten.
- In the Following figure we can see Explosive Charge is placed under the hull at a distance greater than ground clearance of vehicle



Case 2) V-Hull Floor (Bending angle 90°)

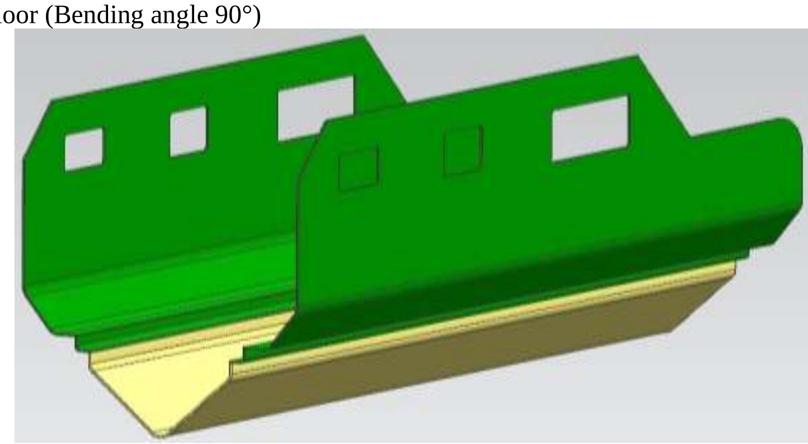
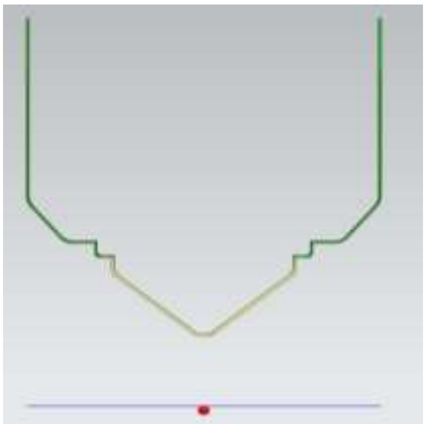


Fig. Armoured vehicle with V- shaped Hull floor (Bending angle 90°)

- In this type of hull bottom portion of vehicle is in angular shape as shown in figure.
- In the Following figure we can see Explosive Charge is placed under the hull at a distance greater than ground clearance of vehicle.



2. BLAST EXPLOSION PHENOMENON

Generally we know Detonation is a process where a shock-wave propagates through a chemical compound and initiates a rapid, exothermic and explosive chemical reaction in its wake. The chemical reaction releases the potential energy of the explosive via a phase transformation process. The detonation wave releases mass of superheated and high-pressure gas. For a landmine the detonation processes can be divided by three phases - explosive interaction with the soil, gas expansion to the surface and soil ejecta interaction with the vehicle. In the present study the soil ejecta are not considered in calculation.

For this simulation we have gone through some basic steps; we put 6 kg SPH model below the hull. High explosive burn material is applied to it and it is blasted. Same procedure is followed for different shaped vehicle and results are compared.

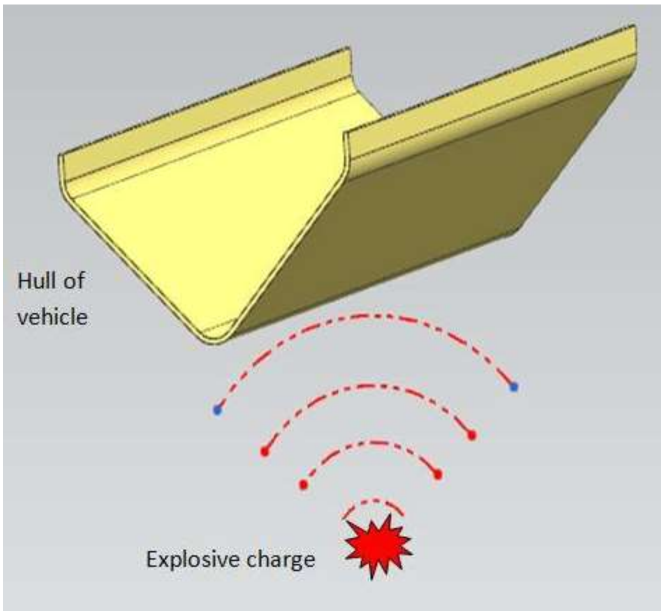


Fig. Experimental Set up

Mine blast impact on hull after explosion phenomenon

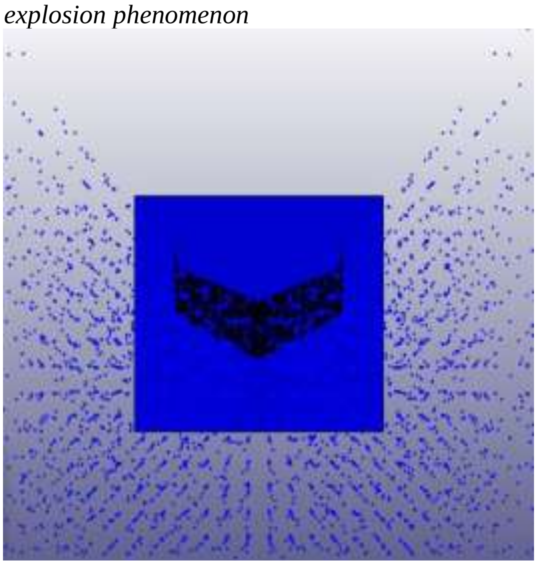


Fig. Dispersion of blast waves due to V-Hull shape

The modified Armoured Vehicles with the V-hull floor shows better blast wave dispersion compared to Armoured Vehicles having the flat hull floor. Also evident from a hull floor fracture occurs in the flat hull floor Armoured Vehicles model, whereas the vehicle with the V-hull floor is deformed without a fracture. A some part of the blast wave enters into the vehicle cabin after the fracture at the flat hull floor ,Which increases the risk of serious injury to the soldiers.

3. FINITE ELEMENT SIMULATION -

Finite element simulations were carried out for two different hulls to study their response to explosion as explained below. Simulation is firstly carried out on flat hull floor to check the general impact on vehicle. Then process is carried out on v shaped hull.

Finite Element Model Building through Hyper Mesh

The Hyper Mesh is used for Finite Element model building. Hulls are presented with shell elements at mid plane surface. Fine meshing of 5mm is given to the hull surface as it gives the accurate result. Accurate FE model generated through Hyper Mesh gave good solver convergence.

Problem solving in Ls Dyna

Ls Dyna explicit solver is mostly used for solving the dynamic analysis problems. It gives wide variety of material modeling and provide lot of contacts according to requirement.

Finite Element setup

For analysing this problem we have to consider two main issues. First blast-loading effects, i.e. forces that are resulted directly from the action of the blast pressure; secondly, the structural response, or the expected damage criteria associated with such loading effects. It is important to consider the interaction of the blast waves with the target . The structural response will depend upon the size, shape and weight of the body.

For this simulation we have placed SPH model at distance of 300 mm below the Hull. High Explosive Burn material is assigned to the SPH and Explosion has been occurred.

Finite Element results

The response of structural elements is generally a consequence of transverse loads with long exposure time and it is generally related with global membrane and shear responses. Therefore, the hull blast loading is referred to as membrane/bending failure. The total energy is contributed only through kinetic and internal energy of the material. Top edge response is measured in terms of acceleration. This acceleration is very important for considering damage inside the vehicle.

Maximum mid displacement is observed for flat geometrical hull and Negative displacement is noticed for V-Shaped hull due to its side's compression inside due to blast pressure, which forces bottom points to go downward. V- shaped hull give minimum positive Z direction displacement as compared to flat hull.

4. CONCLUSIONS

In this paper, the comparisons for the blast response of two Armoured Vehicle models with the flat hull and V-hull floor were shown. The results showed that the vehicle with the V-hull floor angle of 90° has a improved response to blast loading. It is essential when designing safe and effective Armoured Vehicle. This leads to reduced deformations and accelerations of the Armoured Vehicle . hull floor contributing significantly to the improvement of the vehicle as well as Crew's safety. The results presented in this paper are also applicable for protection of civilian, governmental and other facilities for which blast loading assessment is needed.

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