

DEVELOPMENT OF MINE BLAST PROTECTED VEHICLE STRUCTURES FOR FUTURE COMBAT SYSTEMS

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ABSTRACT

One of the survivability challenges to constructing a manned ground vehicle weighing less than 20 tons is ensuring the vehicle's ability to withstand the impulsive forces from an anti-tank landmine blast underneath its structure. By developing structural and appliqué technologies, along with decoupled/shock-limiting restraint systems for the crew, the impulsive forces can be managed for crew survivability. Computational modeling and experiments were conducted with mine protected lower hull structures designed to withstand anti-tank mines. Design concepts and lessons learned were obtained and quantified.

1. INTRODUCTION

Until recently, development of landmine protection technology has been technically challenged by limitations in experimental techniques needed to capture and quantify the blast loading from buried mines in different soil environments as well as limitations with modeling and simulation capabilities. Specifically, the coupling of valid Eulerian blast loadings with Lagrangian finite-element vehicle structures, along with validated material models, has been deficient.

This paper will highlight research efforts conducted jointly by ARL and TARDEC to utilize recent advances in modeling and simulation capabilities, in conjunction with sub- and full-scale experiments, to design, construct, and parametrically evaluate add-on appliqués for vehicle protection.

2. EXPERIMENTAL

For all the experiments described here, the Vertical Impulse Measurement Fixture (VIMF) was utilized to attach the experimental mine protected structures to control vehicle travel and measure imparted blast loads. The VIMF is a structural mechanical device that responds to blast loading by measuring the vertical displacement of a fixed mass vertical guide rail, which is a direct measure of the imparted impulse [Gniazdowski, 2004]. Previous works have described the design of the fixture in detail, Gniazdowski [Gniazdowski, 2004], as well as its ability to measure impulse loads, [Skaggs et al. 2004].

3. RESULTS

Over the past year a design cycle of modeling and experiments have produced two add-on kit designs that provide protection against an anti-tank landmine blast. The two add-on kit designs are designated here as Phase I and Phase II.

The Phase I kit design consisted of a sandwich construction of a S2 glass composite blast face bonded to either a concrete or glass core material, which was then adhesively joined to a steel support structure. The steel structure was wedged shaped and was designed to be very stiff consisting of a longitudinal I-beam spine with lateral steel plate stiffeners, as shown in Figure 1.

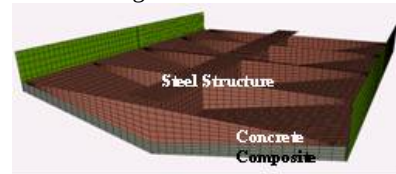


Figure 1. FEA design of Phase I kit

The sandwich structure served to deflect, mitigate, and distribute the impulsive forces from the blast loading and soil ejecta impact into the stiff steel structural backing. The kit was attached to a scaled aluminum hull structure that was approximately 4 ft by 4 ft and outfitted with crossing I beams to form a strong back to attach the hull structure to the VIMF. The quarter scale structure was composed of 6061 aluminum with the sidewall and the crew floor weights at 10.5 psf and 7 psf respectively. Figure 1 presents a pre-experimental photograph of the aluminum structure and kit as attached to the VIMF guide rail.



Figure 2. Photograph of quarter scale aluminum hull structure and wedge kit made of steel, concrete, and S2 composite.

Figure 3 shows the dynamic deformation of the kit at 2 ms.

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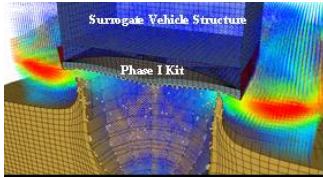


Figure 3. FEA simulation of add on-kit reaction to landmine blast at 2 ms

The resulting design was manufactured, blast experiments conducted, and results compared with the simulations. The structure ultimately failed in the experiment due to web buckling of the steel I-beam, which led to fracture of the I beam web. Post experiment analysis of the internal steel wedge support illustrated that the steel stiffeners deformed and cracked, but as a whole remained intact with no blast or debris penetration. Figure 4 presents comparisons of the steel wedge before and after the experiment.



Figure 4. Before and after experiment photographs of stiff steel wedge structure

The accompanied simulations predicted the onset of the I-beam buckling, but the post-buckled behavior of the web and its ultimate fracture could not be accurately simulated. However, both the simulation and the experiments ultimately revealed the weakness in the design, the cause and location failure, and that the design was overmatched. Thus, a stronger mine blast kit was required. Using lessons learned from the Phase I design led to new numerical simulations to design a more robust kit, denoted Phase II.

For the Phase II kit design, simulations of the interior vehicle floor indicated moderate displacement for a large mine blast. Shown in Figure 5, the Phase II kit consisted of an S2 glass composite blast facing backed by a steel plate.

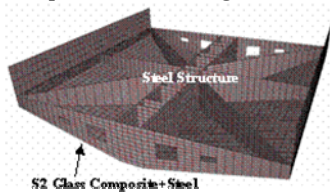


Figure 5. FEA design of Phase II kit

The steel plate was welded onto a stiff steel structure consisting of two longitudinal steel plates having lateral steel support plates welded in a configuration radiating away from center. A thinner steel plate was welded between the two longitudinal plates at set intervals to prevent buckling. A very high strength honeycomb, identified as a promising load filtering/distributing material from laboratory blast panel experiments, was utilized between the steel structure and the lower vehicle hull to help distribute the load over the entire structure. The design was manufactured, experiments were

conducted and Figure 6 presents a photograph of the kit attached to scaled aluminum hull structure.



Figure 6. Photograph of the Phase II kit attached to structure and VIMF guide rail.

An initial experiment, conducted with a moderate charge, resulted in no vehicle floor displacement, so the kit was repaired, including fabrication of lighting holes to reduce weight, and retested with a larger charge, which resulted in some vehicle floor displacement. The kit is currently being repaired and will be subjected to the objective threat. Up to this point, the experimental results qualitatively agree with those predicted by the simulations. Shown in Figure 7 is a sectioned view of the kit deformation at 2 ms, note the minimal floor displacement of the surrogate vehicle.

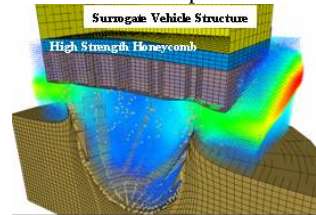


Figure 7. Phase II kit and surrogate vehicle structure simulation at 2ms after landmine blast showing gases venting and minimal deflection of kit and vehicle floor.

The Phase II kit was purposefully designed to survive the most severe land mine blast but in such a way that alternative materials could be used to reduce weight. In the future, further numerical modeling efforts are being performed to further lighten and decrease the profile of the mine kit to include the transition from use of metals and composites to an all composite design.

4. SUMMARY AND FUTURE EXPERIMENTS

The experiments conducted for the two lower hull kit designs have validated numerical model designs and demonstrated survivability. Future models and experiments will be exercised to reduce kit weight and volume in addition to understanding effective attachment schemes.

5. REFERENCES

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