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MONOCOQUE ALUMINUM STRUCTURE DESIGN FOR LIGHT TACTICAL VEHICLE WITH EMPHASIS ON DEFEATING UNDER BODY BLAST EVENT AND IMPROVING CREW SURVIVABILITY

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ABSTRACT

In order to defeat under body blast events and improve crew survivability, a monocoque aluminum cab structure has been designed as a drop on solution based on the current M1151A1 (HMMWV) chassis. The structure is comprised of all 5083-H131 Aluminum alloy armor plates with various thicknesses. The structure design consists of the following new features: (1) Robust joining design utilizing interlocking ballistic joints and mechanical interlocking features, (2) unique B-pillar gusset design connects roof & floor with B-pillar & tunnel, and (3) "Double V" underbody shaping design. The TARDEC designed, integrated & built vehicle achieved no crew core body injuries for a vehicle of this weight class and demonstrated meeting the crew survivability objective when subjected to a 2X blast during the live fire underbody blast tests. These efforts help to not only baseline light tactical vehicle capabilities, but also validate the possibility of meeting aggressive blast objectives for light tactical vehicles. These results provide government-owned designs that are scalable and actionable solutions for future HMMWV fleet upgrades.

INTRODUCTION

PM-LTV's Modernized Expanded Capacity Vehicle-Survivability (MECV-S) program was designed to explore the latest emerging & state-of-the-art survivability solutions and upgrade the Army's High Mobility Multipurpose Wheeled Vehicle (HMMWV) capabilities, particularly focused on crew survivability [1]. The purpose of the vehicle structure with emphasis on defeating under body blast events and improving crew survivability is to have a cab structure to achieve manageable global structure performance during blast. Combined with other counter measures such as adequate stand-off distance, energy absorbing (EA) seats and flooring solutions, the crew will survive at the targeted threat level. The intent of the vehicle is to have the interior cab space that accommodates four (4) crew members plus one (1) additional gunner. The Gross Vehicle Weight (GVW) is designed not to exceed 18,500 lbs. In order to achieve this global structure performance target, a

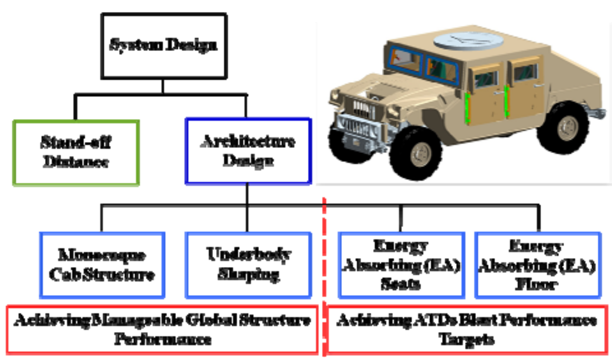

Figure 1: MECV-S System Design Approach.

monocoque aluminum cab structure has been selected. The Monocoque Aluminum Structure Design for Light Tactical Vehicle consists of the following new features: (1) Robust joining design, (2) unique B-pillar gusset design, and (3) "Double V" underbody shaping design.

STRUCTURE DESIGN DETAILS – MONOCOQUE CAB CONSTRUCTION

The Monocoque Aluminum Cab Structure for Light Tactical Vehicle is comprised of all 5083-H131 Aluminum alloy armor plates with various thicknesses (1/2" Inner Floor, 1" Roof & B-Pillar Gussets, 1.5" Tunnel Side Walls, and 2" Underbody Outer Structure, Front, Rear and Side Walls, Tunnel Top "V" Plate; Please see Figure 2 and 3).

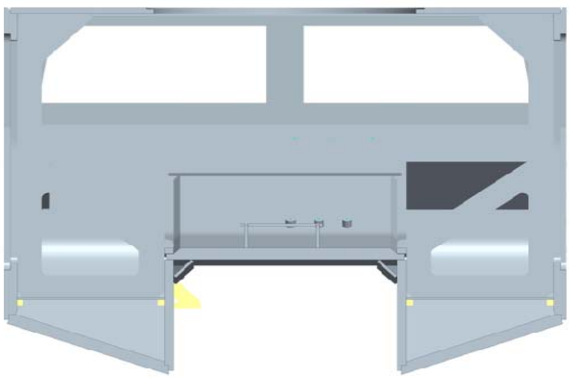

Figure 2: Monocoque Aluminum Cab Structure (front view).

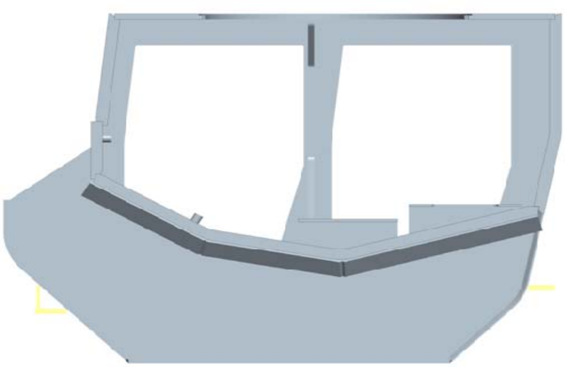

Figure 3: Monocoque Aluminum Cab Structure (side view).

Additionally, the one-piece bend-formed designs of the rear wall, tunnel "V" Top, and front plates provide additional cab stiffness by reducing the amount of weld seams. The whole cab structure is joined by standard Gas Metal Arc Weld (GMAW) which greatly simplifies the manufacturing process and improves the cost and timing of the structure fabrication.

Robust Joining Design

To ensure the integrity of the structure, special attention has been put into the joint designs. Please see Figures 4 and 5 for details. First, wherever possible, mechanical locking in addition to the welded joint has been implemented for breech proof protection, such as at the tunnel top connections. All the other weldments have been provided the interlocking features in addition to the welded connections so that the joints will always be in compressive loading under the predominant failure modes (underbody blast conditions). Finally, cover plates have been implemented on top of the critical joints along the tunnel top to protect the seams from direct hit due to fragmentations or underbody parts becoming loose during blast events.

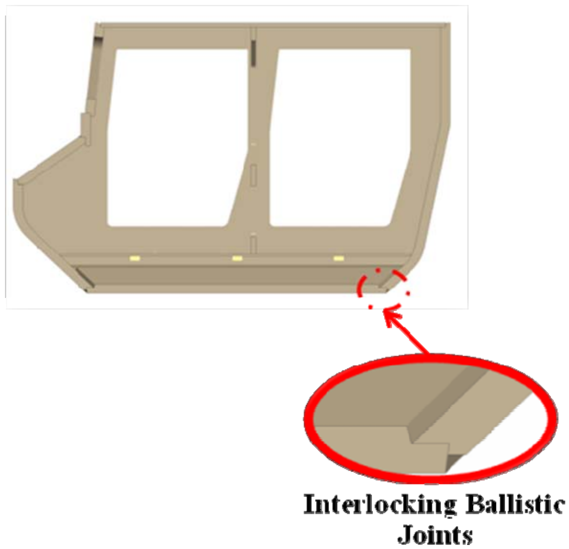

Figure 4: Interlocking Ballistic Joints.

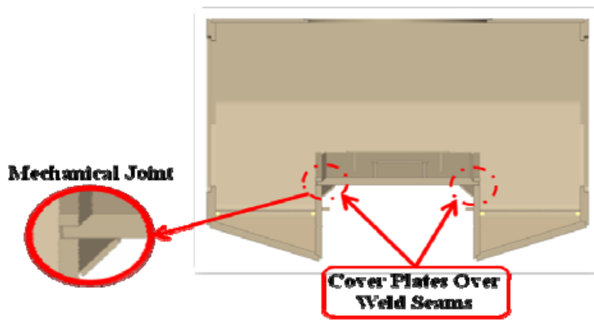

Figure 5: Tunnel Top Joint Design (mechanical locking joints and cover plates).

B-Pillar Gusset Design

One unique design feature for the Monocoque Cab Structure is the added 1" B-Pillar Gussets (see Figures 5 for details). The gussets connect roof & floor with B-pillar & tunnel walls in the middle of the cab where the structural stiffness is relatively lower than the other parts of the cab. These strategically located gussets provide the much needed additional stiffness in the middle of the cab to prevent the cab from bowing laterally. The gussets also help to restrict the amount of crew compartment deformations during the underbody blast events which could improve the cab integrity and crew survivability.

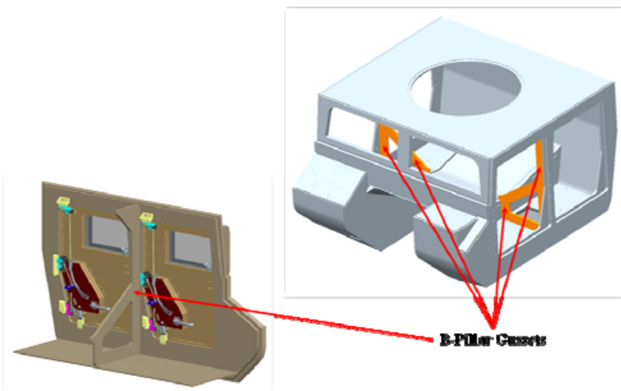

Figure 6: B-Pillar Gussets.

Cab to Frame Mounts

As part of the MECV-S requirements, the up-armored cab is a drop on solution to the current HMMWV chassis. Critical interfaces between the chassis frame to the cab are the cab mounts. The current HMMWV have four (4) mounting hard points. From previous test experiences [2] and modeling & simulation results earlier in the design stage [3], we identified a high risk of the cab separating from the chassis frame during severe events such as underbody blast. To ensure the structural integrity during under body blast events, we added two additional cab-to-frame mounting interfaces in the middle of the cab and frame (see Figures 7).

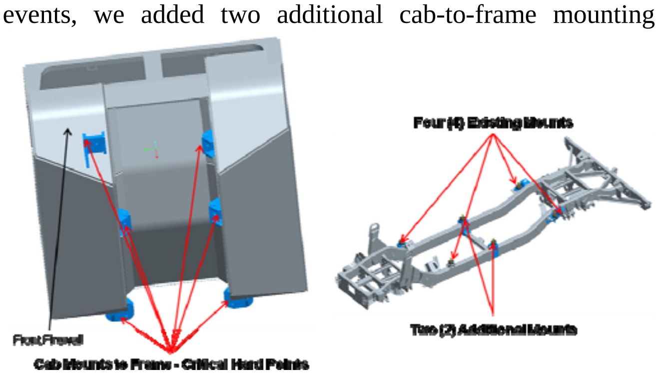

Figure 7: Cab-to-Frame Mounts.

In additional, we implemented post forming machined pockets from the cab side so that the cab mounting brackets have mechanical locking features to ensure the structure integrity (Figure 8).

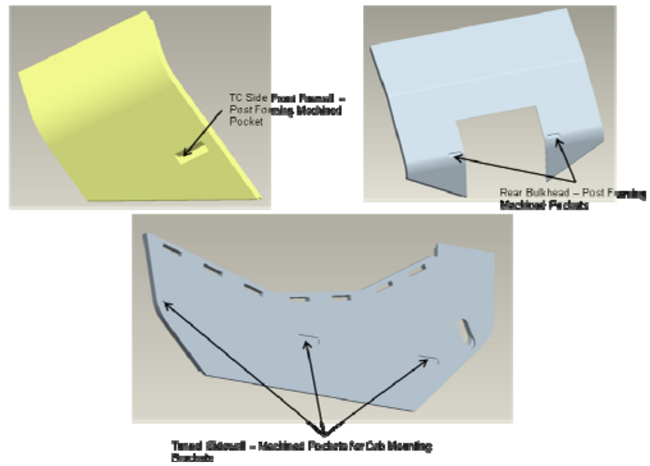

Figure 8: Machined pockets for mechanical locking cab mounting brackets.

"DOUBLE-V" UNDERBODY SHAPING DESIGN

Using underbody shaping to defeat underbody blast events is a complicated design optimization issue. That is, trading the blast deflection performance (the "V" shape) with the stand-off distance.

We included this consideration in another important architectural design feature of the Monocoque Aluminum Cab Structure: the underbody shaping. The "Double V" design consists of a 20^0 side slope under primary and secondary seating areas and a 15^0 aft and 10^0 & 30^0

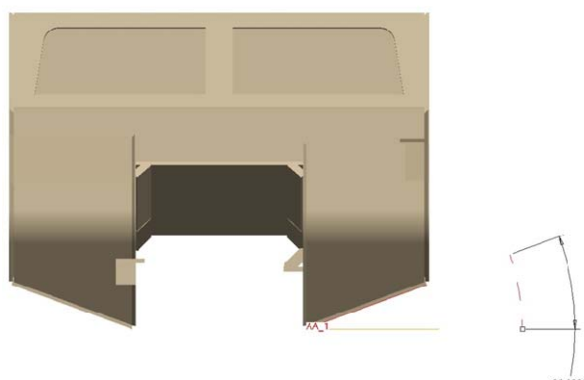

Figure 9: Underbody Shaping – 20^0 side slope under primary seating and secondary areas.

compound angles fore slope at the tunnel top (see Figures 9 and 10).

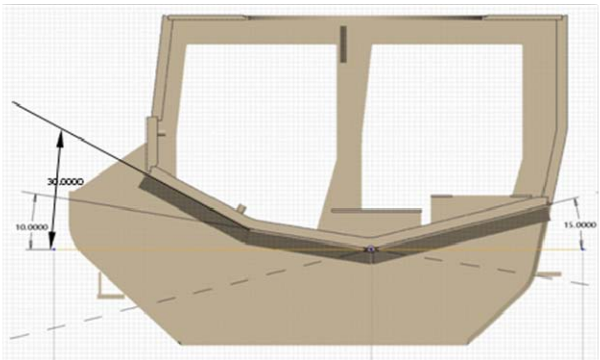

Figure 10: Underbody Shaping – 15^0 aft and 10^0 & 30^0 compound angle fore slope in tunnel.

The underbody shaping will deflect and direct the blast toward the sides, front, and rear of the vehicle away from the crew compartment. This will greatly improve crew survivability. In addition, the unique "Double V" tunnel design allows the tunnel top to be lowered at the center of the cab compared to the current HMMWV cab structure (see Figure 11). In turn, the new Monocoque Cab Structure provides additional usable interior space, particularly in the Gunner area.

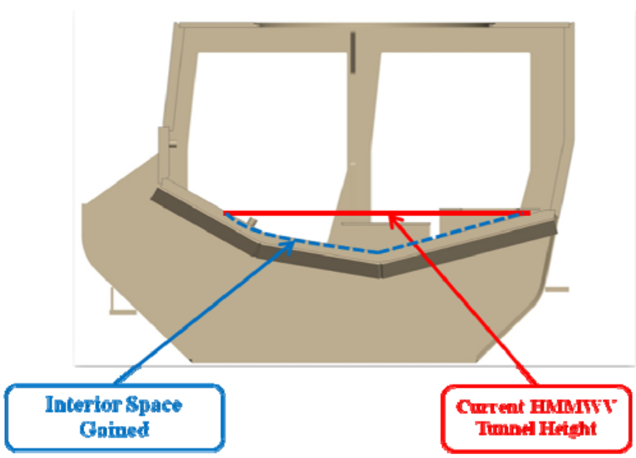

Figure 11: Underbody "Double V" Design provides more useful interior space.

RESULTS

The up-armored blast cab with the above design features targeted at MECV-S requirements was integrated onto a current HMMWV (M1151A1) production chassis. The TARDEC designed, integrated & built vehicle went through live fire underbody blast tests. As a result, through the unique all aluminum monocoque structure, interlocking & mechanical locking joint design, B-Pillar gussets reinforcement, and the underbody shaping design, the vehicle not only outperformed four other industry submissions during the HMMWV MECV-S testing conducted over the period of July to September 2013 but also for the first time achieved no crew core body injuries for a vehicle of this weight class. These efforts help to not only baseline light tactical vehicle capabilities, but also validate the possibility of meeting blast objectives for MECV-like requirements. These results provide government-owned designs that are scalable and actionable solutions for future HMMWV fleet upgrades.

Figure 12: Fully integrated blast cab on existing HMMWV production chassis.

Figure 13: Fully integrated vehicle after underbody blast test.

REFERENCES

[1] Statement of Work Modernized Expanded Capability Vehicle Survivability (MECV-S) W56HZV-12-R-0501

Section C – Description/Specifications/Work Statement, US Army TACOM, January 7, 2013.

[2] J. Capouellez, "Optimized Light Tactical Vehicle," US Army TARDEC, July-Sep. 2009.

[3] V. Babu, "Modeling & Simulation of HMMWV Up-Armored Blast Cab," to be published at National Ground Intelligence Conference, July 2014.