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SELF SEALING FUEL TANKS IN VEHICLES WITHOUT ARMOR

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ABSTRACT

Military vehicle survivability can be enhanced by implementing Lightweight Fuel Tanks with an Engineered Self-Sealing and Energy Absorbing solution. A thin walled plastic or aluminum fuel tank with an outer self-sealing protection coating and a properly installed ballistic baffle provide increased sealing performance as compared to amour protected fuel tank. Design features include reduced weight penalty, survivability, self-sealing against kinetic energy threats, maximum fuel in space claim, flexible design, and low tooling charges.

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1. INTRODUCTION

A ballistic breach from Kinetic Energy threat (*e.g.* 7.62 NATO) into an unprotected Lightweight Fuel Tank (LWFT) is a significant concern. The breach can cause loss of valuable fuel, abandonment of vehicle, ignition of the spilled fuel, and the explosion of the vehicle. A fuel tank breach can pose a serious risk to soldiers in the vicinity.

A "fuel air explosive", the liquid explosive material is dispersed in the air like an aerosol and then ignited, also tends to bring about pure primary blast injury and quaternary effects due to the consumption of all oxygen in the nearby air." Quaternary is defined as: "miscellaneous types of harm due to burns, asphyxia from carbon monoxide or toxic gases, or the inhalation of dust, smoke or contaminants". [1]

Fuel and IED-related burn injuries are at an all-time high. "Not since military operations in Vietnam has the U.S. military medical system experienced the number and severity of burn trauma casualties now attributed to military operations in Iraq and Afghanistan. During the early phases of U.S. military operations in the Global War on Terrorism (GWOT), most of the burn injuries were related to handling fuel and munitions. Subsequently, burns and associated injuries from improvised explosive devices (IEDs) have become more prevalent."- U.S. Army Medical Department Journal. Targeting fuel is a strategy that terrorists have used for years and continue to utilize with devastating effectiveness. [2]

2. LIGHT WEIGHT FUEL TANKS

Fuel tanks on military vehicles can vary in size and shape based on the vehicle mounting method, the fuel volume required, fuel weight distribution and available space on vehicles. Figures 1, 2 and 3 illustrate a few design examples.

Figure 1: Plastic Fuel Tank

Figure 2: Aluminum Fuel Tank

Figure 3: Space Optimized Plastic Fuel Tank [3]

Fuel tanks made of aluminum are very popular in vehicle building. Aluminum has a lower density than steel, generally 0.1 lb/in^3 as compared to steel at 0.29 lb/in^3. Polyethylene tanks are another popular tank construction material at 0.04 lb/in^3.

Plastics generally lacks the stiffness of aluminum at the same wall thicknesses. The typical plastic tank will require a wall 3x thicker than a similar aluminum tank. Unfortunately, plastic tanks will hold less fuel than aluminum tanks within the same space claim.

3. SELF SEALING COATING

A self-sealing coating layer on a LWFT can offer a vehicle builder a weight savings by not requiring armor protection for the fuel tank. A self-sealing coating layer can be applied to the exterior of a fuel tank. The objective is to keep the vehicle operational by preventing fuel tank leakage. Ballistic threats can cause both entrance and exit wounds. Each wound style must be sealed differently to be effective.

Some coating options are hole-minimizing solutions that generally continue to weep, other solutions truly close the hole and remain sealed for years. All coating options should be evaluated based on sealing performance at the required threat level, added vehicle weight and fuel tank capacity.
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4. ENTRANCE WOUND SEALING

Self-sealing coatings can seal entrance penetration wounds for most fuel tanks, as shown in Figure 4.

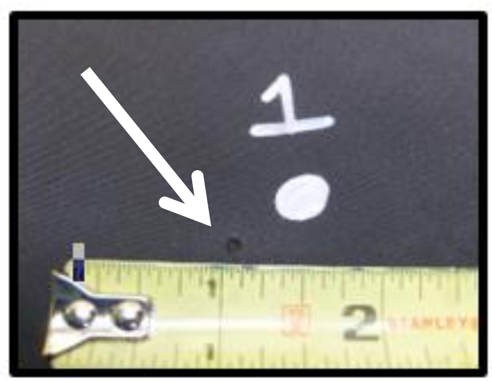


Figure 4: Entrance Wound, Self - Sealed *[3]*

When a bullet impacts and begins to penetrate the exterior wall of the fuel tank, the low compressibility of the fuel within the tank resists the inward deflection of the wall. As the projectile passes through the wall, any deformation (*e.g.* petalling) resulting from the entrance penetration is directed into the fuel tank and away from an external self-sealing coating.

Figure 5 is an example of 1/8 in thick, 5052 Aluminum, fuel tank wall with an entrance wound. The self-sealing coating on the opposite side.

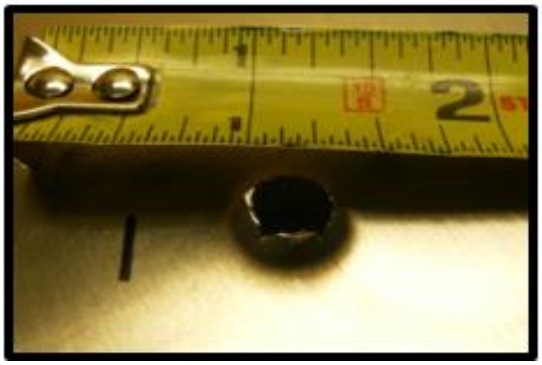


Figure 5: Entrance Wound, Inside Wall *[3]*

5. EXIT WOUND SEALING

In contrast to entrance wounds, it is significantly more difficult for an external self-sealing coating to seal an exit wound in the LWFT.

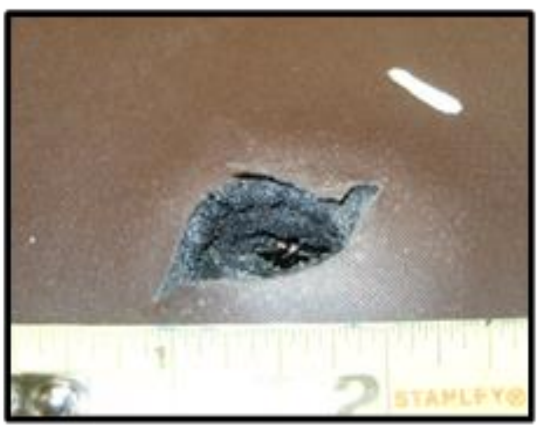


Figure 6: Obstructed self-sealing. [3]

Figure 6 is an exit wound of a 7.62 mm projectile through an 1/8 in thick, 5052 Aluminum, fuel tank wall.

The outer self-sealing coating is obstructed by wall deformation and cannot seal properly.

Figure 7 is the same exit wound as Figure 6. Separation of the self-sealing

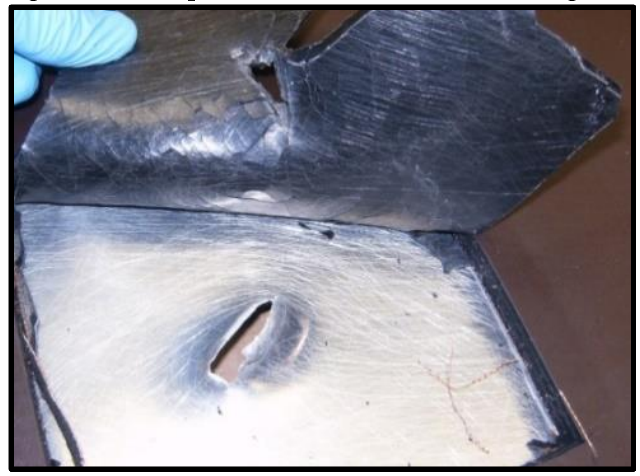


Figure 7: Exit Wound Wall Displaced *[3]*

coating exposes a ductile movement failure of the 5052 Aluminum. Closer examination shows the 7.62 mm projectile tumbled in the fuel prior to penetrating the tank wall.

The deflection of the impacted internal wall is more severe than that of the entrance wall deflection. The deformation resulting from the exit penetration is directed away from the LWFT and into the external self-sealing coating.

Projectile dynamics can also contribute to greater damage at the exit wound. Non-spherical and ogive-shaped projectiles are unstable as they travel through fluid. These projectiles often impact tank walls in a tumbled or off-axis condition. The resulting wound in the wall tends to be in the shape of a large extruded oblong hole (Figure 7). [4] The combination of ductile movement deflection, tumbled projectile and tearing all create a wound that is significantly larger and therefore more difficult to rapidly and completely seal.

LWFT with self-sealing coating works as intended on entrance penetration of 7.62 mm projectiles. If the tank design must be a narrow depth (less than 30”) to fit properly in a vehicle chassis, sealing exit wounds may be difficult when fuel volume is not sufficient to slow the projectile.

6. HYDRODYNAMIC RAM

When the projectile impacts the fluid within the fuel tank, a high-pressure hydrodynamic ram is developed, as the bullet travels through the fluid. [5] During a Hydrodynamic Ram (HRAM) event, the growth and collapse of a large cavitation bubble generated by the transfer of kinetic energy, from a projectile as it moves through a liquid container, is transferred to the surrounding fluid resulting in the formation and growth of an expanding bubble interface and a corresponding drop in local static pressure below the vapor pressure of the liquid. [5]

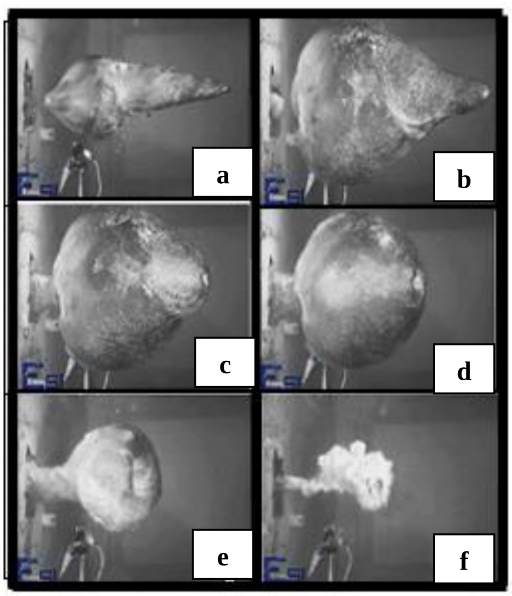


Figure 7: Hydrodynamic Ram Event Showing the Growth of a Cavitation Bubble and Its Collapse [5].

Figure 7 shows a sequence of 6 images of how a large cavitation bubble grows when a projectile penetrates a water filled container. Images 7a – 7c shows its expansion to a maximum size in image 7d (approximately 10” (25.4 mm) in diameter). The following two images 7e and 7f show how the bubble collapses in on itself forming a re-entrant jet, as detailed on the right side of the cavitation bubble in image 7e. This implosion may produce extremely large pressures, as high as 1000 psi, and can result in catastrophic failure of the liquid container [5].

Since fuel tanks are not pressure vessels, the high-pressure pre-strains the tank walls and contributes to greater tank damage. It is common to see aluminum fuel tank seams split, and plastic tanks have cracked walls. [3]

7. Energy Absorbing Baffle

To mitigate the transfer of kinetic energy, from a projectile into the fuel, the Energy Absorbing Baffle was developed. The objective is to slow and possibly fracture the projectile to dissipate the Kinetic Energy prior to the commencement of the HRAM. Shown below in Figure 8, an Energy Absorbing Baffle is positioned within the interior volume of the test fixture.

Figure 8: Energy Absorbing Baffle *[3]*

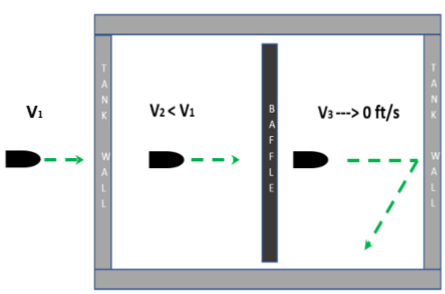
Baffles are constructed with sufficient thickness, hardness, toughness, *etc*., to meaningfully reduce the projectile's ability to create a damaging exit wound. The baffle can cause fragmentation of the projectile (i.e., breaking up of the large high energy projectile into multiple smaller lower energy projectiles)

Figure 9: Low Energy Projectile Particles *[3]*

after impacting the baffle (Figure 9). The baffle eliminates or reduces the size of exit penetrations and allows for optimized tank size and increased fuel capacity (Figure 10).

Figure 11 illustrates how the projectile velocity changes as it penetrates the tank wall and the energy absorbing baffle.

Figure 10: Exit wall Results with Energy Absorbing Baffle *[3]*



8. Conclusion:

For a military vehicle, a Lightweight Fuel Tank can be utilized when coated with a performance rated self-sealing coating. Vehicle builders and armoring companies can offer fuel tank protection without adding heavy armor plate. High velocity projectiles striking a fuel tank can be sealed effectively at its entrance wounds.

Lightweight Fuel Tank projectile exit wounds can be catastrophic due to the 1000+ psi implosion energy from the Hydrodynamic Ram. Tanks can be designed with energy absorbing baffles and self-sealing coatings to alleviate the risk and focus on increased performance and survivability.

Lightweight Fuel Tanks reduce weight, increase fuel capacity, and improve soldier survivability.

Figure 11 illustrates the projectile velocity changes [3]

9. REFERENCES

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