Prof. Jozef Kosacki’s

Military Institute of Engineer Technology

50-961 Wroclaw, 136 Obornicka Street
www.witi.wroc.pl
Protection of Combat Vehicles against Mines: Design Concepts

Janusz Sliwinski,
Cezary Sliwinski,
Patrycja Wojcieszynska,
Wacław Malej
Introduction

Military conflicts involve a wide-spread use of different kinds of vehicles, including fighting vehicles, armoured vehicles, personnel carriers and mine-clearing vehicles.

They are used to conduct military operations, patrol missions, convoys, mine-clearing-, and routine transport missions. During these operations, the vehicles can encounter both mines and Improvised Explosive Devices (IEDs).
Threat caused by typical AT mines, projectiles guided from upper hemisphere, from RPG launchers and IEDs:

1 – typical pressure-activated AT blast mine,
2 – typical non-contact fuse AT blast mine,
3 – scatterable AT shaped charge mine whose impact is exerted underneath the hull of the vehicle,
4 – scatterable AT shaped charge mine whose impact is exerted on the upper hemisphere of the vehicle hull,
5 – rocket-propelled off-route shaped charge mine.
6 – off-route EFP (explosively formed penetrator) mine,
7 – RPG,
8 – IED containing high-explosives,
9 – IED containing a shaped charge.
In asymmetric warfare, IEDs are used most often. The lessons learned from the local conflicts (such as the Balkan conflict), the Russian-Afghan war and the experience of the Polish contingent in Afghanistan, indicate that mines and IEDs play a significant role as one of the more efficient weapons. They enable effective resistance to the better equipped soldiers of the world’s wealthiest armies to be posed by the insurgents.

If in an IED, the explosive content of which equals 50 kg, explodes this practically guarantees that each and every combat vehicle, the latest generation of MRAPs and battle tanks included, will be destroyed.
A concept of equipping a tank with an explosion-proof armour

Diagram of the impact of explosion-proof armour and signature duplication systems on AT mines:
1 – scatterable shaped-charge AT mine (on ground surface); 2 – scatterable shaped-charge AT mine (under a battle tank) 3 – tilt rod full width attack mines; 4 – typical magnetic influence fused; 5 – off-route mine

The tests conducted indicated that even the elements with weakest armour on the bottom of the battle tank, with the flexible, multi-layer armour equipped were capable of withstanding the impact of modern scatterable AT mines.
Based on the results obtained via testing of the explosion on the flexible armour and the impact of a shaped charge mine, it must be assumed that flexible explosion-proof armour should be characterized by being multilayered and containing joined (either with an adhesive or via vulcanization) elastomeric (e.g. rubber) bands, alternating with technical fibres (such as carbon ones or aramid ones). Having been mounted to the tank, the armour was weight, and its mass equalled ca. 560 kg, plus the tensioning mechanism (ca. 100 kg), which would make the total mass to be about 650 kg. This would not impact the tank dynamics in a significant manner, but it would greatly improve the crew safety during operations in area infected with mines and IEDs.

Flexible multilayer armour:
1 – elastomeric tape, 2 – carbon fibre fabric
Impact of explosion on flexible armour

WITI conducted tests aimed at the weakening of the blast wave by a flexible armour. In order to achieve that, a flexible armour made of rubber and weighing 20 kg (dimensions: $3000 \times 800 \times 8$ mm) was placed over a standard block of TNT – 15 cm above ground. The ratio of the mass of the armour to the mass of the explosive charge equalled $K = 50$ (20 kg/0.4 kg).

The analyses and partial tests indicated that the flexible multilayer armour was indeed suitable as protection of the lower part of combat vehicle hulls, since it both dissipates and absorbs a significant portion of blast wave energy. This results from the fact that rubber is characterised by low sound propagation velocity ($V = 30\div60$ m/s), much smaller than that of other structural materials (steel $V \approx 5000\div6000$ m/s, aluminium $V \approx 6300$ m/s, composites $V \approx 3500$ m/s), or air itself ($V \approx 340$ m/s). In the field tests, the armour dissipated ca. 50% of blast energy.
The idea of equipping an armoured personnel carrier (APC) and a mine-resistant vehicle (MRAP) in an explosion-proof set

The favourable shape of „V-shaped” underside, as far as dissipation of a significant part of energy is concerned is contrasted with its negative consequence, namely accumulation of the part of explosion energy which had not been dissipated within the vehicle hull. This fact resulted in WITI deciding to initiate analyses into either the elimination, or at least significant limitation of this unfavourable phenomenon.

The findings from the analyses are the following: blast wave is a spatially-wide, mechanical wave, propagating in material media (solids, fluids and gasses) only, and it would not propagate in a vacuum. These properties were taken into consideration by researchers in WITI when developing an idea for an explosion-proof set for an armoured personnel carrier (Polish: KTO) and an MRAP.
The idea of equipping an armoured personnel carrier (APC) and a mine-resistant vehicle (MRAP) in an explosion-proof set

KTO vehicle concept (on the left hand-side) and MRAP vehicle (on the right) with explosion-proof set attached:
1 – flexible explosion-proof armour, 2 – container with vacuum, 3 – double wrap panel, 4 – protective panel, 5 – supporting ropes, 6 – brackets, 7 – lower bottom, 8 – upper bottom
Rope explosion-proof panel is to be used to protect the underside of vehicle hull against the impact of blast wave generated as the result of a detonation of explosive.

Rope explosion-proof panel – frontal view (A); panel with suppressing layers exposed (B) – top view; panel mounted to the bottom plate and arch plate of a combat vehicle (C) panel section suppressing layers exposed (D)
Optimal selection of explosion-proof panel for a fighting vehicle requires comparative tests of various kinds of panels and armours.

Modular construction of a test stand for tests of an explosion-proof panels
1-body, 2-exchangable bottom, 3-chassis with wheel-axle assembly, measurement device, 5-measurement sensors
Dynamic tests stand for explosion-proof armour

The panels will be tested with regard to:

a) their **mass**;

b) **sound propagation velocity** in the panel;

c) **mechanical strength** parameters under:
   - static stress (universal testing machine);
   - dynamic stress (pendulum-based tests);
   - impact load (explosive test stand);

d) estimation of **energy absorbed** by the pannel with regard to the unit of weight;

e) **pressure pulsation in crew compartment** resulting from the impact of blast wave which had propadated into the crew compartment.
Conclusions

1. Contemporary military conflicts see wide employment of mine warfare, that is the use of various mines and IEDs.

2. Optimal (streamlined) vehicle hull underside design, its reinforcement, increased ground clearance and the application of explosion energy suppressing measures decreases the efficiency of the mine and IEDs’ impact on the vehicle hull underside.

3. The idea of explosion-proof multilayer flexible armour for a tank, the explosion-proof set for the KTO and MRAP vehicles and rope explosion-proof panel are possible means of increasing the protection level of the hull underside’s resistance to the above-mentioned range of threats.

4. Explosion-proof multilayer flexible armour intercepts fragmentation, disturbs the impact of a superplastic metal jet and an explosively-formed projectile (EFP). It also partially disperses the blast-wave generated by a high explosive detonation.

5. Development of explosion-proof panels characterised by high energy absorption parameters requires a number of comparative tests using different test stands.
Thank you for your attention