4th DAAAM International Conference on
Advanced Technologies for Developing Countries
September 21-24, 2005
Slavonski Brod, Croatia

MODELLING OF ALL PROTECTED VEHICLES

D. Mikulić, V. Stojković, T. Gašparić

Key words: development of protected vehicles, humanitarian mine-protected vehicle, escort vehicles in peace-keeping operations, mine-protected vehicles, ballistic-protected vehicles

1. Introduction

All-protected vehicles (APV) have been designed to provide a safe and secure multi-purpose vehicle for peacekeeping operations and humanitarian operation. Mine-protected vehicles (MPV) are specially designed to protect the crew from mine threats in humanitarian demining. This paper provides the principles of All-protected vehicles calculation and design based on high mobility terrain vehicle 4x4 in accordance with NATO requirements for countermine crew protection in logistics vehicles.

All-protected vehicles are integral part of demining mechanization. They are used as supporting/escort vehicles in machine demining, but primarily they are used for demining crew transportation to the demining site. From this vehicle, later on, the demining vehicle is remotely controlled. Such vehicles have to be resistant to mines that could appear in mine-suspicious area. The Republic of Croatia is the leading country in machine demining, and the priority task of protected vehicle design in machine demining is set up, available as transporter or citadel.

2. Basic requirements

The basic requirements include:

- Total vehicle mass 10 t,
- Maximal speed of 130 km/h,
- Possibility to transport 10 people (transporter),
- Modular variant – citadel,
- High vehicle clearance,
- Countermine protection in accordance with NATO standard,
- Possibility to upgrade the weapon station,
- Fast crew entry and exit,
- Air transported, C-130

The standard level of crew protection against weapons and mines / Standard STANAG 4569:

- Level 1 protection / option: level 2 /level 3, peace-keeping operations, intensity conflicts
- Countermine protection: level 2 mine vehicle protection, 6 kg TNT / level 3 - 8 kg TNT.

STANAG 4569 is the basic document for protection levels for occupants of logistic and light armoured vehicles, as stated in Annexes A and B. The list of protection levels is based on 90% probability of providing protection for crewmembers in case of certain threat/danger. For countermine vehicles in humanitarian demining the second level of countermine protection is applied and the first ballistic protection level from ammunition and mine fragments.

3. Vehicle design

Fig. 1: APV transporter/carrier, countermine and ballistic protection

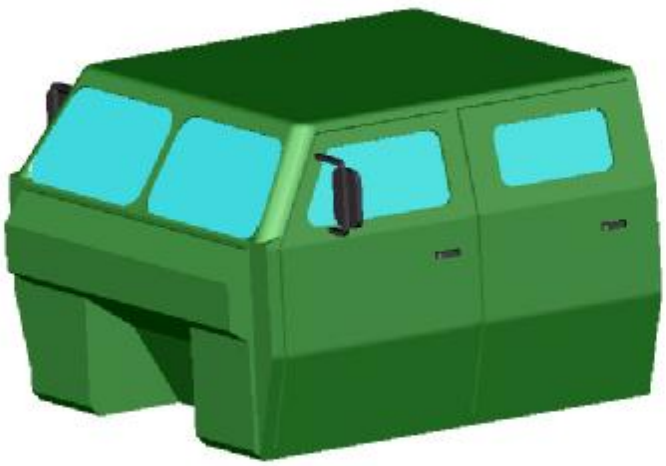

Fig. 2: Citadel, All protection

4. AT mine blast calculation

In the calculation theory of explosion effects on vehicles the goal is to transform physical features of mine detonation into engineering models, in shape of load spectrum primarily of overpressure and blast impulse from the centre of explosion toward the vehicle as well as other parameters of blast in characteristic intervals. At floorboard and sides of vehicle construction, a load spectrum on exposed surfaces and vehicle is determined at the moment when mine detonates under the middle surface of the vehicle, wheels and at its sides. It provides the basis for countermine vehicles calculation that provides protection to crew from fragments, noise and blast vibrations.

Mine protected vehicles have to pass experimental testing for AT mines explosions. It is necessary to determine the parameters of vehicle load variations on the basic AT mines of 6 kg mass of TNT for 2a and 2b protection level. In addition, it is very important to be familiar with load spectrum and other mine threats for man and vehicle, for example the basic AP mine of 200 g mass of TNT, AP and PROM-1 spring-blasting mines.

4.1. Blast pressure under the vehicle

Basic data for blasting wave calculations:

Name/type of explosive, TNT, 6 kg of explosive, ratio Qe/Qe(TNT) = 1

Explosion conditions: detonation at the surface

/calculation by Sadovski equation/ M. Suceska, Brodarski institut, Zagreb/

R – distance from the explosion centre (radius effect);

p_u – shock wave pressure;

p_d – detonation products pressure.

The calculation results of shock wave under the vehicle and wheels are given in Table 1 and the diagram on dependency of pressure to distance of explosion centre, Fig. 3.

Table 1 – Pressure dependence on distance of explosion centre

R (m)	p_u (kbar)	R (m)	p_d (kbar)
0.09	97.59	0	196.58
0.1	71.27	0.01	82.31
0.125	36.66	0.02	36.75
0.15	21.31	0.039	12.41
0.2	9.07	0.054	7.17
0.3	2.74	0.069	3.86
0.4	1.18	0.106	0.92
0.5	0.61	0.177	0.23
0.6	0.36	0.244	0.10
0.7	0.23	0.577	0.01

Under the vehicle at 50 cm from the ground to the floorboard, the pressure of the shock wave generated by an AT mine with 6 kg of TNT is approximately 600 bars. The spherical effects of shock wave are expected from the detonation centre to periphery at a radius of R /~15º. To shock wave pressure height and chassis surface a shock force is formed that should be absorbed. Because of that, a spherical chassis form is considered for protection at safe distance R and V-shape of vehicle sides. The solution is usually provided as double floorboard or false bottom.

If the wheel activates an AT mine of 6 kg mass of TNT, it is destroyed by detonation products pressure. In a radius of 1 cm, the pressure of those effects is approximately 80000 bars; by increasing the radius up to 50 cm, its effects are completely lost. Wheels are run-flat equipped that should allow V-shape directing of detonation products in order to lower the wheels' impact on the vehicle. If the wheels are not equipped with the run-flat option, the vehicle will suffer major damage from an AT mine explosion. Under the wheels the

detonation products pressure p_d is dominant and under the vehicle, for the floorboard construction, the shock wave pressure p_u is dominant.

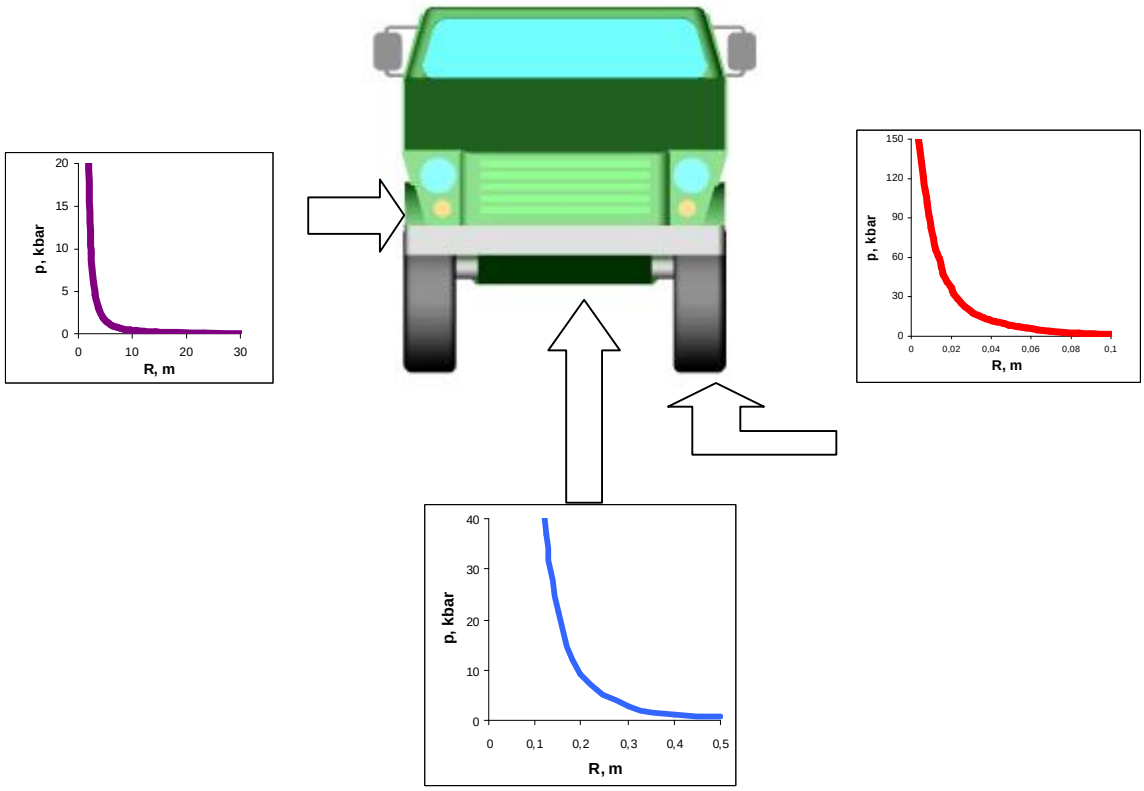

Fig. 3 - Protection valuation of APV and MPV from shock wave pressure of AT mine under the vehicle, wheels and at vehicle sides

5. Safety Compartment, citadel

The safety compartment / citadel is protected against mine attack by a multi-layered undercarriage structure. This consists of a sandwich construction, which is designed to absorb the fragmenting mine blasts and can be enhanced to protect against anti-tank mines through the fitting of a blast shield. The key to surviving mine blast is effective absorption or dissipation of energy. The complete mine protection subsystem consists of the following elements: deflector system, crew safety compartment with false floors, blast mounting for deflector and crew compartment, damping elements for the seats, 4-point safety belts.

Instead of the original driver's cab, APV and MPV should have a citadel / safety compartment. Citadel can be specially designed and is produced according to a special technology called "thin-plate-bending", eliminating most of the welding. The compartment should have a large, armoured front window providing an outstanding field of view for the driver, also equipped with armoured glass (one or two parts). The resistant roof on the hardtop version provides protection against grenade fragments affecting it directly. Most of the armour protection should be modular being adapted to the basic structure of the safety compartment.

Seats that are built in into countermine vehicle should protect humans from blast vibrations (at least 10g). In addition, a seat has to provide stabile position and has to be designed according to ergonomic principles; the seats have to reduce vibration as much as possible. Seat design has to endure all the stretching that can emerge in its exploitation, as well as in case of overturning.

6. Protection from impulse noise and vibrations

When countermine vehicles and demining machines are designed, crew safety is the most important factor. When mine explodes under the vehicle, or very close to the vehicle, a shock wave is created and spread in all directions faster than the speed of sound. This wave surrounds the machine cabin creating floor, roof and overall coating vibrations, which creates overpressure inside the cabin.

The intensity of explosion blast (impulse noise in) is determined based on the sound pressure (overpressure). The highest noise level should not exceed the allowed values for the hearing organs. At overpressure higher than 200 Pa (140 dB) the safety measures should be applied (ear protectors, protective helmet). Outer machine parts influence the noise level, thickness of armoured plate provides reduction of noise level within the cabin. The length of impulse noise of one AT mine explosion close to the vehicle is 14ms, and the noise burst rate is 160 dB. In addition, ear protectors reduce the noise by 25 dB, which can be considered as protected. Such a blast can damage unprotected ears but also internal organs that are filled with air.

Shock effects on the vehicle body create vibrations and sudden changes of personnel position which can result in complex injuries of feet and ankles, if feet are placed on the floor and injuries of spine because of the vertical seat motion. High exposure to vibrations increases the risk of spine injuries and pain in its lumbar part. Extremely high blast values, such as driving through rough terrains or mine explosion under the vehicle can cause spine fracture. In addition, long exposure to lower blast values can cause degeneration of spine discus, which leads to constant pain. Limitations to vibration exposure: A) spine: Average acceleration value < 15 g or max value of velocity change < 4.5 m/s or VDV <10 m/s (DRI<16), B) foot/ankle: Average acceleration value < 20 g or max value of velocity change < 3 m/s.

7. Conclusion

Vehicles should be more and more of countermine and ballistic design. Such vehicles should be procured according to safety standards. For humanitarian demining as well as for military vehicles requirements, the same protection level from AT mines can be defined. Although there is regulation for countermine protection levels for military vehicles - STANAG 4569 – there are so far no International Standards for All Protected Vehicle Testing and Evaluation. That is why it is so important do develop the Technical criteria for Survivability and Acceptance, and Repeatable conditions.

The APV Project emphasizes the need for transporter type of vehicle and for citadel type of vehicle. The total vehicle mass will depend on these types. The most important parameters in MPV design to AT mine threats are vehicle clearance height, double floor, deflectors, independent wheel suspension, run-flat tyres, countermine seat, impulse noise protection. To chassis design, the most important is shock wave pressure; for the wheels, the most important is detonation products pressure. This paper provides more blasting wave parameters in order to be able to evaluate possible vehicle protection.

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Dinko Mikulić, Ph.D.
MoD - Directorate for development and modernization, Bauerova 33, HR-10000 Zagreb, Croatia,
e-mail: dinko.mikulic@morh.hr, dinko.mikulic@fsb.hr

Vjekoslav Stojković, Ph.D.
Polytechnic College Velika Gorica, Zagrebačka cesta 5, HR-10410 Velika Gorica, Croatia,
e-mail: vjekoslav.stojkovic@vvg.hr

Tomislav Gašparić, dipl. ing.
Faculty of Mechanical Engineering and Naval Architecture, Lučićeva 5, HR-10000 Zagreb, Croatia,
e-mail: tgasparic@fsb.hr, dok-ing@dok-ing.hr