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Options for Increasing the Safety and Improvement of the Protection of Military Mobile Technology

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Abstract. Military vehicles and equipment should be designed with regard to ergonomics, which is important for the protection of the crew. Reliable protection can be achieved by constant technological progress and the improvement of materials, enabling resistance of an attack by mines and improvised explosive devices (IED) placed under the vehicle. The explosion of a device under a vehicle represents a great risk for its crew. This paper is about the protection systems that are using in the World and provide a comprehensive and effective protection of the vehicles. The mainly task of these systems is to safe the crew. The paper divides the protective anti-mine system into the external protection system and internal protection system. Each of these two basic groups is nearly specify in the text and there are also application examples for military mobile technology. In the end to sum the paper up there are some approaches to improvement of safety and protection of the vehicles.
Keywords: military mobile technology, safety and protection, explosion, materials

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1. INTRODUCTION

Trends in protective systems provide the comprehensive and effective protection of the vehicle, which the safety of the crew is derived from. Features of comprehensive protection systems are following [1]:

- avoiding the direct exposure of the crew to the shock wave,
- prevention of the penetration of projectiles and fragments using special materials,
- absorbing vast amounts of explosive energy by a protective floor.

Additional protection of the crew is achieved by installing special seats and special equipment, for the effects of shocks reduction (Fig. 1).

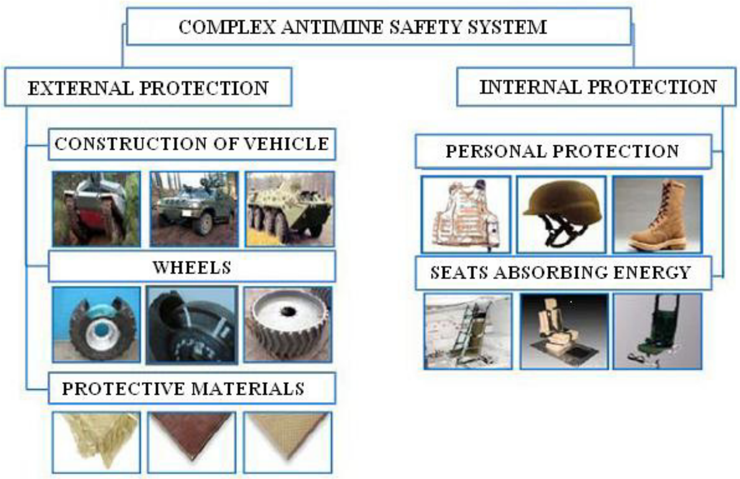

Fig. 1. Complex anti-mine safety system [1]

2. SYSTEMS OF PROTECTION

The security system of the vehicle can be divided into two groups showing the protective anti-mine system [1]:

- the external protection system,
- the internal protection system.

2.1. The external protection system

External protection reflects and absorbs the majority of the explosions energy, thus reducing the load that is transmitted to the crew. It also prevents the penetration of shock waves and shrapnel into the vehicle's interior.

2.1.1. The design of the vehicle floor

Protection of vehicles against landmines in terms of the base construction generally follows several directions. It deals with shock-wave deflection, fragments, and damps down the energy of an explosion and prevents rollover.

The standard approach is to use a single-floored design (called the „basic bottom"). The bottom of the vehicle is made of only one layer of armour. From the introduced vehicles in the Armed Forces of the Slovak Republic, the vehicles shown in Fig. 2 and Fig. 3 use a single-floor construction on the bottom. These vehicles are the Alligator and IFV-2. The double-floored construction of the bottom (called the „double bottom") consists of two parallel layers of armor. The space between the layers can be filled with air, ceramic, plastic or other materials which are able to absorb partially the explosive energy.

Fig. 2. Vehicle Alligator [2]

Fig. 3. Vehicle IFV-2 [3]

This approach is used in the vehicle TATRAPAN, which is in service in the Armed Forces of the Slovak Republic (Fig. 4). The crew is protected from the IED in form of landmines by a specially designed double bottom. The space between the armour layers of the bottom is filled with air.

An important role in the construction solution of the vehicle bottom plays the angle under which it faces pressure waves, therefore a very effective construction of the bottom is in shape of the letter „V" (called „V-bottom"). This element of protection comes from South Africa, where studies and tests on anti-mine protection vehicles have been conducted for more than two decades (since the early seventies until the end of the eighties). The obtained results of the activities are due to the fundamental construction of the bottom in shape of sharp „V", which, combined with highly resistant shell, effectively reflects the largest shockwave from bombs exploding directly beneath the vehicle or under the wheel. This solution also provides partial protection against the shaped charge mine as the bumper is not falling at a right angle [4].

Fig. 4. Vehicle TATRAPAN [2]

Based on the concept of the V-bottom, the South African industry has created the vehicle CASSPIR. This vehicle is capable of withstanding a powerful explosion from 18 kg to 20 kg of TNT [4]. The concept is still used even in modern vehicles, such as the Australian ADI Bushmaster 4×4, American Buffalo (Fig. 5 and Fig. 6) and British OCELOT. The Armed Forces of the Slovak Republic have not put a vehicle with that element of external protection into effect yet (Fig. 5) demonstrates how the shock wave is carried in the vehicle with the „V” shape bottom.

Fig. 5. Vehicle Buffalo [5]

Fig. 6. Explosion of an explosive device under the vehicle Buffalo [6]

The general disadvantage is to combine this type of bottom with the classical requirements for a low silhouette and good passage of the vehicle. Despite the disadvantages, vehicles with the V-bottom are increasingly preferred for the use in the present crisis areas.

2.1.2. The „Run flat" system

Performing the tasks during combat operations, wheels have to withstand exposure of firearms or shrapnel from explosive devices. They can cause so high damage to tires that even the central tire inflation system cannot support further trip and the vehicle becomes immobile.

The „Run flat" system is used to solve this problem (Fig. 7). However does not reduce the negative effects of the IED detonation to the crew. Its importance is to increase probability that the attacked vehicle will not lose its mobility. Furthermore, the mobile vehicle will not become an obstacle, blocking other vehicles in the convoy, being still capable to move away from the so-called „killing zone", thereby protecting it and its crew against further potential attacks.

Fig. 7. The „Run flat" system [7]

Wheels included in a „Run flat" system allow it to operate in different terrains and with different tire pressures. They do not affect handling or speed.

2.1.3. Special materials

The ideal material used for the protection of the vehicle should be as efficient and as simple as possible. Armoured materials are divided into two different categories, according to their material properties and the way they can react to the energy exerted. The first category consists of materials which reflect the energy into space and the second category include the energy-absorbing materials [8].

Reflecting materials are characterized by high hardness and strength. These include steel or ceramic materials.

It crushes the incoming fragments by dispersing kinetic energy of the fragment and its subsequent fragmentation, and the fragmented particles are drifted by the reflected energy out of the protective structure [8].

On the other hand, absorbing materials absorb the kinetic energy of fragments and transform it into another form of energy such as heat or consume it in plastic deformation.

The most protective systems include both reflecting and absorbing materials, which form together composite armour. This kind of armour can provide greater protection against the risk of the penetration of fragments than in classical homogeneous armour.

So far, the mentioned materials are involved in the elimination of primary, secondary and tertiary injuries, which occur only in the case of breaching the integrity of the vehicle external protection. The material called „CRUSHMAT" (Fig. 8 and Fig. 9) performs different functions. It reduces shock caused by impact of pressure waves at the bottom of the vehicle, thus reduces risk of the tertiary injuries. „CRUSHMAT" is made up of ceramic granules, consisting of unbound granular aluminium oxide (Al_2O_3). It is able to absorb high explosive energy, consumed mainly for crushing the material. The amount of energy can reach value of up to 2100 J per 1 kg of granules [9].

Fig. 8. Material „CRUSHMAT" before explosion [10]

Fig. 9. Material „CRUSHMAT" after explosion [10]

The use of the material „CRUSHMAT" for the external protection of the vehicle brings with it [10]:

- The reduction of the energy transmitted to the supporting structure,
- Damping of high acceleration, which the crew would be exposed to,
- The reduction in the risk of the floor in the vehicle braking,
- A reduction in the burden of welds and bolts concerning the vehicles structure,

- A light weight protection system is of light weight (material density „CRUSHMAT" is about 600 kg/m^3),
- Flexibility in terms of the design of the protection system,
- A minimal need for structural change when it comes to increasing the protection of the vehicles.

The material „CRUSHMAT" cannot ensure the protection of the vehicle alone. It is used to fill in spaces between armour plates. Such combination ensures the optimal protection against a widespread shock, and also flying fragments of shrapnel.

In order to determine effectiveness of the mentioned material, some tests were performed to compare a standard armoured protection consisting of a homogeneous shell of the equivalent weight using the „CRUSHMAT" protection system. Tests showed that the vehicle protected by the „CRUSHMAT" material suffered minor damage, and the driver was subject to less load as compared to the driver of the vehicle with conventional armour protection. The protection with the use of the material „CRUSHMAT" offers 60-70% less power and will keep the 25-30% reduction in the applied acceleration relating to conventional armour protection with equivalent mass [10].

2.2. The internal protection system

Internal protection of the vehicle is designed to protect the crew from the negative effects of an explosion, which external protection is unable to eliminate.

2.2.1. Protection against debris

Important role in the safety of the crew plays a mat called „Spall liner" (mat against debris). „Spall liner" (Fig. 10) is the material used to cover the vehicle interior in order to reduce the risk of intrusion of debris after an attack on the exterior surface. Most commonly it consists of: nylon fabric, polyethylene fibres, para-aramid fibre or polyurethane [11].

Fig. 10. Captured armour wreck in „Spall liner” material [11]

The mat protects people from [11]:

- ceramic and metal fragments, released from the surface of the shell, as a result of its rapid deformation,
- fast-flying fragments.

2.2.2. Seats

The seat is a link between the human body and vehicle. Through the seat the body carries load not eliminated by external protection system. It should therefore be designed to avoid exposure to the residual energy of the occupants as much as possible. Vehicles equipped with conventional seats are not able to guarantee adequate security, particularly when the external protection system consists of only an ordinary single-layer homogeneous armour. There is no effective mechanism to absorb energy in this case [12].

Existing vehicles of high degree anti-mine resistance are equipped with seats to absorb energy. The main function in the design of these seats is to reduce significantly the load transmitted to the people seated, which contributes to an increase in the probability of the crews survival when exposed to an explosion. The seats should be fasten to the floor, as has always been in the past. It is advisable to attach them to the walls or ceiling of the vehicle. Figure 11 and Fig. 12 show the means of fixing a special seat. The distance between the seat and the floor should ensure that any deformation of the floor is not intervened with the occupant.

The seats should be well padded and they must also fulfil the ergonomic requirements [13]. In this case, their correct position is guaranteed in the vertical and also horizontal movement of the vehicle. An integral part of the seat is the footrest and the headrest. Of course, a safety belt of at least four-point with a simple and rapid release cannot be overlooked.

Fig. 11. Safety seats attached to the wall of the vehicle [5]

Fig. 12. Safety seats attached to the ceiling of the vehicle [5]

3. CONCLUSIONS

Basic approaches to the improvement of the safety and protection of the mobile equipment can be summarized as follows:

- The bottom of the vehicle should in order to reduce the negative effects that causes injuries to the crew,
- To cover the floor with a special pad, which prevents penetration of fragments or shrapnel into the combat area,
- Ammunition placed away from the bottom of the vehicle to prevent initiation and explosion in its interior,
- The seats attached to the ceiling or walls of the vehicles construction. the distance between them and the floor must ensure that any deformation of the floor will not affect the person or persons seated,
- Each seat equipped with at least a four-point safety belt with a simple and rapid release mechanism,
- Avoiding the installation of the driver pedals directly onto the floor,
- The electrical system and fuel system specially designed to prevent ignition or explosion of fuel in the case of electrical short circuit.

The uncompromising acceptance of all of these solutions is possible only in the case of newly designed vehicle. Very extensive modernization would be required to use the above mentioned approaches for the existing vehicles.

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