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MILITARY VEHICLE SURVIVABILITY IN THE CONTEMPORARY BATTLEFIELD

Abstract. The article presents technical solutions that enhance the survivability of military vehicles and crew protection, as well as analysis of the latest solutions and trends in this field. Particular attention is given to threats that emerged during recent military operations, which is why the scope of considerations is limited to wheeled armoured vehicles that were used in these operations. Modern solutions and trends in the construction of this type of armoured vehicles are also analyzed. NATO directives on ballistic protection of vehicles are also referred to, and trends in the modernization of the Polish Armed Forces' armaments are presented in the perspective of recent military operations abroad.

Keywords: military operations, vehicle and crew safety and survival.

1. INTRODUCTION

Modern military vehicles should have the following features [16]:

- modular design and compatibility of the vehicle units with those of other vehicles;
- high mobility;
- rail and air transportability (dimensions and weight);
- high level of crew protection provided by:
  - rapidly installed add-on armour;
  - vehicle bottom mine protection;
  - the possibility of installing additional equipment (adapted for operations in urban and mountainous terrain, active self-defence systems);
  - high level of survival in the battlefield;
  - crew comfort.

As seen above, one of the most important characteristics of the vehicles used in combat operations is crew protection and its survival in the battlefield.

However, the survival of military vehicles is a broad problem that is connected with very important aspects of personnel and equipment safety. Therefore, the main goal of the article was limited to presenting and assessing technical solutions in the context of protecting crews of military vehicles, as well as analyzing the latest solutions and trends in this area.

2. THE NATURE AND DISTINCTIVE FEATURES OF MODERN MILITARY OPERATIONS

A new type of armed conflict emerged in the last decade of the 20th century and the beginning of this century. In the traditional approach, war is understood as the use of military force in international relations against the territorial integrity and political independence of other states. In recent years, however, armed conflicts have become a more local phenomenon of ethnic, religious or cultural nature. These conflicts often go beyond the borders of one country to become international or internationalized conflicts. They also penetrate deeply into

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social life, quickly becoming a part of reality. At the same time, these conflicts, due to the differing understanding and definitions of international community, significantly influence the concept of crisis management in the global system [20].

Contemporary wars and armed conflicts have no homogeneous grounds. Regardless of where they take place, they affect (though to a different extent) the entire international community. This is due to both the deepening of economic relations, increased migration, as well as wider access to modern military technology. In addition, modern media techniques make information about wars instantly and globally available.

There have also appeared asymmetric wars, where the asymmetry does not arise from the difference in potential, but from the dissimilarity of the opponents [14]. Asymmetry is any form of threat to which the institutions (of the state, coalition, alliance) are not prepared culturally, structurally, intellectually, or from a legislative, administrative or regulatory point of view, so as to be able to respond immediately, effectively and sharply [28]. Asymmetric wars are wars without frontlines, battlefields, logistics, where the opponent of the state is not a subject of international law, and thus is not constrained by any restrictions, and the state has no symmetrical possibilities of opposing the threat, when non-state armed forces are a party to the conflict. This type of forces is particularly dangerous and destabilizing, not following any rules or norms. Asymmetrical threats are a very broad phenomenon, and thus difficult to define, and they affect both the military and non-military sphere. They usually arise in poor countries, seeking revenge on the rich, who are blamed for their bad situation. Common methods involved in asymmetric actions include threats, terrorist attacks, kidnapping and extortion [15]. These threats occur now, and may occur in the future. Their essence consists in shifting the centre of gravity from typical threats, armed conflicts, to non-standard threats, which are difficult to identify, as they may be unknown non-state entities [19]. A typical example of asymmetrical operations are the military operations in Iraq and Afghanistan (Table 1).

Table 1. Comparison of conflict types [7]

	Conventional war	**Guerrilla warfare**	**Terrorism**
Forces	large (army, corps, division)	medium (battalion, company, platoon)	small (units of less than 10 men)
Arms	all (including air forces and navy)	light infantry weapons, at times light artillery	small arms, grenades, explosives
Tactics	joint operations of all forces	special operations	kidnapping, murder, hostage-taking, bomb traps and extortion
Targets	military/dual-use	mainly military, administration, police forces	symbols, political opponents, civilians
Task	physical elimination of the opponent	usually physical elimination of the opponent	break the opponent mentally
Uniforms	yes	often yes	

3. THE MOST COMMON THREATS DURING RECENT MILITARY OPERATIONS

The participation of soldiers in military operations generates a number of threats for them. Currently, the biggest threat during operations involving Polish soldiers are IEDs

(Improvised Explosive Devices). These are home-made explosive charges put together using ordinary, simple devices of everyday use. Using them gives the opponent a big advantage, because soldiers are not able to control every piece of terrain, and during patrols such charges are difficult to detect. The enemy also often uses some conceiving and masking elements that distract or attract to increase the effect of firing such charges. Strafing fire from mortars, grenade launchers and machine guns is another combat and direct threat from the enemy. This threat is difficult to eliminate and combat, because the opponent disappears immediately after the attack, melting with the surrounding crowd or pretending to be one of the local inhabitants [26]. The statistics of soldiers fallen in foreign operations based on ISAF and IF operational reports clearly indicates that during recent military operations most Polish soldiers died as a result of the impact of IEDs or of fire engagement during combat operations, especially with the use of grenade launchers. This gives grounds to state that the greatest future combat threats for soldiers serving abroad will also be those of this type.

Although operations abroad are associated with safety threats and, unfortunately, there is no way to avoid them completely, it should be noted, however, that certain undertakings can minimize or reduce the hazards to soldiers. These include proper preparation, organization of actions and weapon systems, which include soldiers' field gear and other team equipment. If these undertakings are made skilfully, fatality figures should be lower.

Recent military operations may be regarded as an arms race in which guerrillas use increasingly stronger explosives, change the design and placement of the explosive charges, and change their tactics of ambush, use simple minefields, etc. Therefore, one of the most important contemporary technical problems is to increase the resistance of military vehicles to the effects of an explosion-induced shock wave. The main problem arises when effective protection is to be provided for the crew of armoured vehicles and internal equipment against IEDs [12]. In view of that many armies are bringing into service modern armoured vehicles which are increasingly effective in protecting soldiers.

4. MODERN SOLUTIONS AND TRENDS IN THE CONSTRUCTION OF ARMOURED VEHICLES

Conducting asymmetrical operations resulted in the abandonment of large, heavy and very expensive tracked vehicles in favour of light wheeled armoured vehicles. The first vehicle of this type was the American HMMWV, or High Mobility Multi-Purpose Wheeled Vehicle, the production of which began in the 1990s. The first vehicles had a reinforced drive system, new seats, and modified electrical system. After two years, a new, more powerful engine was installed, the lighting was changed, electronic controls for the drive system and a new interior ventilation and heating system were added, the cargo space and capacity were increased, the structure was strengthened. However, experience gained so far during operations in Afghanistan and Iraq showed that the HMMW, used with success in the first phase of the fighting, did not provide soldiers with adequate protection not only against anti-tank grenade launchers, but also against mines and IEDs [8]. Therefore, a new design of high field mobility [14] and adequate ballistic and mine protection [30] was required.

In response to this demand, the Mine Resistant Ambush Protected (MRAP) programme was developed in the US at the beginning of 2007. This resulted in a wide range of vehicles of this type being brought into service in the US Army and in other countries [5]. The introduction of mine-resistant vehicles in Afghanistan and Iraq resulted in the reduction of casualties among soldiers participating in military operations.

Since November 17, 2008, the most numerous MRAP-type vehicle in the Polish Military Contingent in Afghanistan was the RG–31 Cougar [6]. After their introduction, the Cougars took over most of the tasks executed before by the HMMWVs. Between November

2008 and April 2009 there were three IED attacks on Cougars. The most serious was when an explosive charge of an estimated weight of 5 to 8 kg exploded under the front axle of the vehicle. The explosion tore off the fenders along with the air filter and damaged the pneumatic and ABS systems. Although the vehicle suffered relatively minor damages, it could not be driven on its own. However, it was possible to tow it. The second event was the explosion of an IED that probably consisted of several mortar shells and an anti-personnel mine - a total of about 2 kg of explosives. The explosion punctured the tyre of the front right wheel. Another explosion under the vehicle, of a charge of several kilograms, caused no damage [12]. In all three cases, no soldier was killed, which seems to be the most important advantage of the RG-31 design, which is able to ensure the survival of the crew during the explosion of a high blast force charge. An improvised explosive device weighing about 100 kg was detonated under this vehicle. Despite the destruction and damage, the crew of this vehicle had survived.

MRAP (Mine Ressistant Ambush Protected) series of armoured military vehicles with increased resistance to mines and ambush attacks is manufactured by Oshkosh Corporation. The Pentagon has purchased over 20 thousand of these vehicles for nearly US$ 50 billion. The manufacturer set the MRAP on the chassis of a 6-wheeled truck with a TAK-4 independent suspension system. This reduces vehicle rocking, making it easier for the gunner to fire more accurately. The vehicle is equipped with a central wheel pumping system and run flat tyres, which makes it possible to drive almost 50 kilometres with two damaged tyres. The 370-hp Caterpillar C7 engine with the Allison 3500 SP six-gear automatic transmission and the Marmon Herrington transfer case allows the vehicle to travel at 105 kilometre per hour. M-ATV (MRAP All Terrain Vehicle) has a cab with a V-shaped bottom, designed to disperse as much energy of an exploding mine or an improvised explosive device as possible, the cab being protected by an armour of ceramic composites. The basic version of the off-road MRAP has a weight of 11,340 kg, takes in 5 soldiers, including driver and gunner. It can be fit with a 7.62 or 12.5 mm machine gun, placed in an armoured turret protecting the gunner. Alternatively, it can be fitted with an anti-tank guided missile launcher or with a 40-mm automatic grenade launcher [12]. According to specifications, the M-ATV resists an explosion of a 10-kg TNT charge. Unfortunately, the charge that exploded under a MRAP vehicle on December 21, 2011, and contributed to the death of five Polish soldiers, was ten times stronger. Even a much larger vehicle would not survive such a blast force.

Apart from the advantages mentioned above, these vehicles also have drawbacks [18]:

- the considerable weight of the vehicle makes it difficult to transport, e.g. by air;
- low fuel economy, difficulty crossing the terrain;
- height of the vehicle – facilitates detection and firing at by enemy;
- high centre of gravity reduces the vehicle's stability and increases the likelihood of it tipping over, especially in hilly terrain.

The MRAP programme includes three categories of vehicles differing in purpose, weight and dimensions. Category I includes lighter (least resistant) vehicles, dubbed MRUV (Mine Resistant Utility Vehicle). These are used mainly in urban operations. They feature a 4x4 drivetrain, crew of 6, mine blast protection of 7 kg TNT on hull and 14 kg TNT under wheels. This group includes: Armor Holdings Caiman, Force ProtectionCougar H 4x4 (in service with the Polish forces in Afghanistan), International Maxx-Pro.

Category II MRAPs includes 6x6 vehicles, with a crew of up to 10, 15 kg TNT blast protection on hull and 21 kg TNT under wheels. Vehicles of this category are dubbed JERRV (Joint EOD Rapid Response Vehicle) and are designed for various missions: explosive ordnance disposal, troop transport, convoy lead. This group includes: Force Protection Cougar HE 6x6, International MaxxPro XL.

Category III includes the heaviest vehicles, MPCV (Mine Protected Clerance Vehicle), which feature blast protection of similar level as category II vehicles. These vehicles are equipped with a characteristic arm, a manipulator enabling the examination (neutralization) of suspicious ordnance by the operator inside the vehicle. This category is represented by MRAP Force Protection Buffalo.

In Poland, work was limited to prototype constructions of MRAP-type off-road vehicles. One of the examples is a vehicle designed by Germaz company and the Wrocław University of Science and Technology. The vehicle has a Level 4 armour according to NATO standards and weighs 12,240 kg. Another example is the AMZ construction, that is TUR vehicle, which has a Level 2 armour according to STANAG 4569, which can be upgraded to Level 3 which provides protection against 7.62×51 and 7.62×54 machine gun fire. The cabin provides the crew with protection against 7.62 mm armour-piercing shells.

Meanwhile, a growing number of countries are bringing new, light armoured vehicles to service in their armies. In 2011 the Australians purchased Hawkei vehicles of their domestic manufacture. The Hawkei has a modular armour ("B-kit") made of composites and resistant to strikes with 7.62x51 shells fired from 30 metres. Protection against mines (ca. 6-8 kg TNT) is provided by the vehicle bottom with a V-shaped deflector, cabin floor separated from the chassis and crew seats that absorb energy of the shock wave. The vehicle is powered by a Steyr M16 SCI six-cylinder turbocharged diesel engine (cubic capacity 3.2 litres) providing a power output of 268 hp at 4000 rpm. The transmission is automatic with six forward gears and one rear gear. Maximum speed is 130 km/h. Kerb weight is 7 tonnes, gross weight 10.2 tonnes [9].

Light wheeled vehicles adapted to negotiate terrain obstacles, including water obstacles, have become necessary in the service of special and reconnaissance troops. Due to their ability to move in difficult terrain, they are often called "all-terrain vehicles". Due to their low weight and dimensions (low and compact shape) they can be air-lifted. One of such vehicles is the British SUPACAT 6x6. It is a particularly successful vehicle design, as it can not only move soldiers and loads, but also single-axle trailers, mortars and cannons [24]. The British have developed two vehicles for their armed forces based on Land Rover design: M-WMIK (Weapons Mount Installation Kit) and Jackal-Supacat HMT. The M-WMIK, of which 130 were purchased, was used for British missions in Iraq and Afghanistan. The vehicle in its standard version has dimensions of 3.2x1.8 m, a mass of 3100 kg, maximum speed 130 km/h. It is powered by a Diesel engine with a cubic capacity of 4.2 litres. The vehicle can be armed with a 7.62 mm machine gun and a 25 mm automatic grenade launcher, or alternatively with a 12.7 mm machine gun and a 40 mm grenade launcher. M-WMIK is a manoeuvrable and fast vehicle, especially suitable for difficult Afghan terrain conditions. Initially these vehicles were not provided with an armour for protecting the crew. At a later stage they were fitted with Mapik system from Jankel Ltd, consisting of lightweight demountable and portable panels. However, they have no protection against mines and IEDs, which meant that it was of little use under the Afghan conditions (as was the case with category II MRAP mine-resistant vehicles) [13].

The other British vehicle, the Jackal-Supacat HMT (Jackal), had superior arms and armour, which was the reason it superseded the M-WMIK in Afghanistan. The advantage of these seven-ton vehicles is their exceptional mobility and good armament (7.62 mm machine guns and a 40 mm automatic grenade launcher from Heckler & Koch ALGL). Maximum speed is 130 km/h. The vehicle is able to negotiate vertical obstacles up to 1 m tall. Its armour also has better specifications than that of its predecessor: components of UBOS – Underbody Blast Protection Systems. Unfortunately, it was not designed with a view to provide better protection against mines and IEDs [4].

Since 2003 the German Army has in its service the Serval light vehicles from Rheinmetall Landsysteme. These vehicles are characterized by high reliability and efficient performance in mountainous and off-road terrain. They are equipped with containers with smoke grenades, mounted on bumpers, and sensors in the tyres that deploy a smoke screen at the moment of tyre puncture. In addition they are fitted with an RLS609K weapon station that accepts a 12.7 mm machine gun or a 40 mm automatic grenade launcher. There are mounts in the front and back of the vehicle for 7.62 mm machine guns. The Serval takes a crew of four and is powered by a 2.7-litre Diesel engine and has an external armour on its hull and bulletproof glass panes. The underside is reinforced with protective panels, the body has holders for additional armour and payload. However, the Germans have not decided to transfer these vehicles to Afghanistan. The German Bundeswehr put emphasis on the safety of soldiers and sent its army to Afghanistan equipped with vehicles with increased resistance to mine and IED explosions under the vehicles. These vehicles were Dingo 1 and Dingo 2 [9].

The Austrian Achleitner company manufactured a modular patrol vehicle PMV (Protected Mission Vehicle) Survivor II 4x4 with dimensions of 5750x2400x2700 and kerb weight of 10.2-11.5 t (six- or eight-men versions) powered by a MAN D0836 Diesel engine producing an output of 206 kW. The vehicle can attain a speed of 100 km/h and drive in water up to 1.1 m deep. The wheels are provided with inserts that enable driving with punctured tyres [1]. The heaviest version of the Survivor II provides ballistic protection of Level 3 according to STANAG 4569 and mine blast protection of Level 3b (8 kg TNT under each wheel). The windows have bulletproof glass panes that provide second level of protection. The monocoque armoured cabin made of armour steel is combined with the frame by means of flexible links. The interior of the cabin is protected against 20 mm shells. In the case of detonation of a mine under the wheels, the shock wave is dispersed by the shape of the cabin underside and by crumple zones. All seats are mounted separately to absorb shock effects after detonation of mines and IEDs. They have mechanically adjustable backrest and seat height as well as four-point seat belts [2].

The French have a floating wheeled armoured personnel carrier, VAB Vehicule de l'Avant Blinde (armoured vanguard vehicle), the production of which was launched in 1974. Two versions of the VAB wheeled armoured carrier were manufactured: four-wheeled 4x4 and six-wheeled 6x6 designed to carry 10 soldiers, manufactured in GIAT Industriers plant at Saint-Chamond. The vehicle is in service with the French armed forces, as well as with those of Cyprus, Morocco, Lebanon. It was used in combat operations in Kuwait, Yugoslavia and Africa. This body of the carrier is made of armour plates resistant to small arms. Firing ports are arranged on both sides of the vehicle body. A 255 hp (188 kW) Renault MDR Diesel engine enables the vehicle to develop a maximum road speed of 90 km/h, 7 km/h on water. It is capable of crossing ditches up to 1.5 m wide and walls up to 0.65 m tall. It is fitted with a 7.62 mm machine gun and a 12.7 mm heavy machine gun. It can be optionally fitted with 25 mm Dragar cannon and antitank rockets. Another vehicle used by the French army is ERC 90 Sagaie (Engine de Reconnaissance, Canon). This combat reconnaissance vehicle, manufactured since 1984, takes a crew of three: driver, gunner and commander. It has a 10 mm monolithic steel and composite armour, and a six-cylinder Peugot PRV petrol engine developing an output power of 114 kW. It is fitted with a 90 mm Giat F4 cannon [2].

As mentioned before, a huge threat to the vehicles are land mines and IEDs. IEDs are being constantly improved and have become a very dangerous weapon for vehicles and people, especially because of their simplicity, and therefore the possibility of widespread use. In view of the above, some methods of reducing threats from IEDs have also been developed, but terrorists are also improving their tactics and design of mine traps. Therefore, in order to protect the soldiers, MRAPs and Duke-type frequency jamming equipment was put into

service. Seeing that their attacks are ineffective, the militants began to use explosive charges shifted in relation to the fuse [2] (Fig. 1).

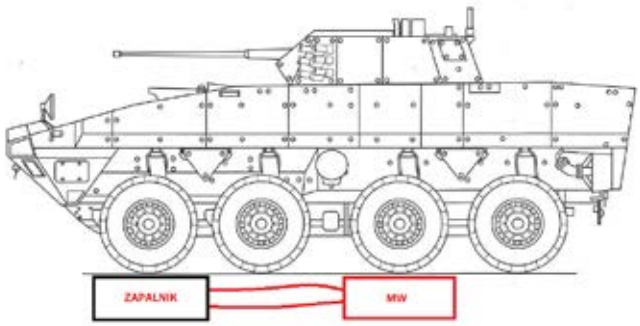

Fig. 1. One of the ways of deploying mine traps by the militants
Source: author's study

The response to shifted pressure fuses was the use of minesweepers (Fig. 2.), which in turn caused that the distance between fuses and explosives was increased and detonations under the hull still continued to occur. The solution to this problem may be the use of an automatic system for controlling the distance between the minesweeper and the vehicle (Fig. 3.) With this solution, the enemy will not be able to clearly determine in advance the distance between the fuses and the explosive charges. This is a preliminary suggestion that requires detailed elaboration, but it seems that such a solution would reduce the risk of vehicle crew fatalities.

Fig. 2. MRAP with minesweepers [11]

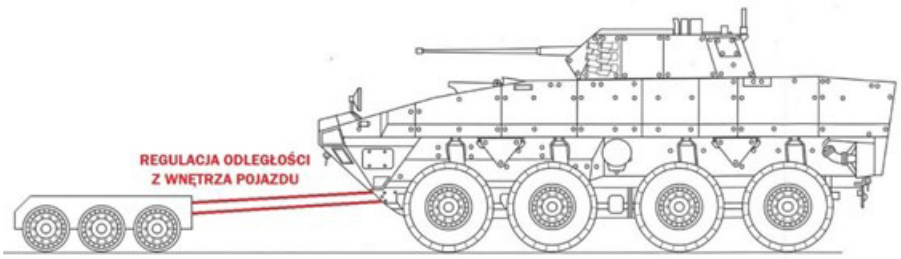

Fig. 3. A proposed solution for the protection of crew against the method of fuse shifting
Source: author's study

In general, the vehicles of the future (armoured and armour-plated) should meet the following requirements:

- interoperability;
- capability to operate in a network-centric battlefield;
- air transportability;
- high vitality (survivability);
- high firepower;
- modular structure;
- simplicity of use.

5. STANDARDIZATION OF NATO REQUIREMENTS IN THE AREA OF VEHICLE BALLISTIC PROTECTION

According to the data presented in the previous section, the biggest threat to troops in the danger zone are mine traps, IEDs, mortar shelling of military bases, high explosive missiles (PG-7 type and other). It should be noted that so far no method has been found to effectively identify and neutralize IEDs, and the terrorist tactics acquire the nature of guerrilla or indirect warfare [17]. Against such practices, special IED detection measures were adopted: pulse-induction panel detectors, and radio jamming equipment on patrol and convoy vehicles. Therefore, military vehicles should meet specific requirements so as to effectively protect the vehicle crew - soldiers performing their tasks.

There is a NATO document constituting the basis for setting appropriate requirements for ballistic protection of military vehicles. That is STANAG 4569: NATO Standardization Agreement covering the standards for the "Protection Levels for Occupants of Logistic and Light Armoured Vehicles". The aim of the agreement is to standardize protection levels for armoured vehicle occupants to ensure that: [24]:

- commanders in the field can select the right equipment to fulfil a mission under the given threat;
- NATO member states have a planning guide to deploy the appropriate equipment to address theatre specific threats;
- member states can develop and upgrade their equipment to match given threats.

The protection level list is based on a 90% probability of providing protection to the occupants of military vehicles at a given threat. Annex A to STANAG 4569 distinguishes 5 levels of protection against penetration by bullets and fragments of artillery shells. It covers standard rifle and armour-piercing ammunition of the following calibres: 5.56 mm, 7.62 mm, 14.5 mm and 25 mm. Levels of protection against penetration by artillery shell fragments

depend on the estimated range of burst of a 155 mm shell. Annex B to STANAG 4569 specifies levels of protection against penetration by grenade and blast mine fragments.

Individual STANAG 4569 criteria implemented in the armies of member states are used to develop test procedures during the design or modernization of military vehicles. The essence of the issue is the assessment of the probability of exposure of the life of vehicle crew to attack with various warfare agents for a given vehicle design and selected material systems [29].

Most of the European armies are equipped with light military vehicles intended for the transport of patrol teams of 4-5 soldiers. Examples of protection systems in such vehicles in some countries are as follows:

1) German DINGO 2, protection system - 7.62x54 AP (SWD) all-round (STANAG 4569 partly Level 3 bulletproofness 0) and 7 kg AT mine;
2) American HMMWV M1114, protection system – 7,62x51 M80 all-round at 100 m distance, including glass panes, 6-kg AT mine front (Level 2a – STANAG 4569 Annex B), 2-kg mine rear (4-door vehicle), 155 mm shell fragments at 100 m distance (Level 1 STANAG 4569 resistance to fragment strikes);
3) Swiss EAGLE IV, protection system – Level 3 STANAG 4569 bulletproofness, Level 2a STANAG 4569 resistance to blast mine threats;
4) Polish SKORPION 3 based on HONKERA 2000, protection system 7.62x51 NATO Ball - selected surfaces, excl. glass panes (partly Level 1 bulletproofness acc. to STANAG 4569), 7.62x39 PS – selected surfaces, excl. glass panes, AP mines – selected surfaces;
5) AMV ROSOMAK, protection system – Level 4 acc. to STANAG 4569, resistance to AT mines Level 3a acc. to STANAG 4569.

To recapitulate, the effectiveness of armour of military vehicles used in various military operations, in areas of terrorist attacks or of subversive group activity, from the point of view of crew protection, is extremely important. The effectiveness of the vehicle's armour ensures an adequate level of safety for its crew, but also affects the survival of the vehicle in the battlefield. A certificate for armour material is not a guarantee of effective ballistic protection of the vehicle (probability of crew survival). The assessment of the effectiveness of crew protection should take into account the hazards occurring in a given area [29].

6. MODERNIZATION OF THE VEHICLES OF THE POLISH ARMED FORCES IN THE AREA OF INCREASING CREW SAFETY

Due to the participation of the Polish Military Contingent in military operations in Iraq and Afghanistan, the quantity and quality of equipment of operational units has increased. Just a general comparison of military equipment in Operation Iraqi Freedom in 2004 and ISAF in 2011 illustrates how massive changes have taken place in this respect (Table 2) [27].

Table 2. Comparison of the equipment used by the Polish Military Contingent in operations: IF in 2004 and ISAF in 2011 [27]

Item	Iraq 2004	Afghanistan 2011
1.	Night vision instruments of old PNL-2AD type, prone to failure when directed to an intense light source.	Night vision instrument MU-3AD. Sharper image with higher contrast. The night vision instrument can be mounted on a Beryl rail and aligned with a holographic sight.
2.	Old type Kevlar helmet with an uncomfortable clasp that is difficult to unfasten and fasten with gloved hands.	New type helmet. Improved and more comfortable fastening. A leather pad for the neck in rear part. Soldiers have balaclavas.
3.	OLV bulletproof vest, heavy, makes breathing difficult, with non-ergonomic pockets, long - making it difficult to sit down and lie down. All pockets positioned permanently, no change possible.	New generation UKO type modular bulletproof vest with quick release system. Provides protection for shoulders, neck, abdomen and back bottom. Much more resistant to shell fragments and bullets than the older version.
4.	Old Beryl type rifle. Initially without front grip and without rail for mounting accessories. It had a metal opaque magazine and a traditional sling, without tritium sight illumination.	New version of Beryl rifle. Provided with a modified folding adjustable butt, transparent plastic magazine, factory mounted mounting rails on rifle stock and an adjustable additional grip. A more convenient, improved selector switch allows the weapon to be unlocked faster with one finger. Magazine release, holographic sight and tritium illumination of traditional sights have been modified.
5.	Soldiers had no knee pads or elbow pads. They had no balaclavas.	Soldiers have knee pads and elbow pads.
6.	Honkers in 2004 had no armour.	Rosomak provides soldiers with much better protection during operations.

Nowadays wheeled armoured personnel carriers are increasingly dominating the modern armies of the world, and carry out tasks previously designed for tracked vehicles. This is, among other things, because contemporary armed conflicts have the nature of asymmetrical expeditionary operations, rather than of fighting armoured mechanized units. Another reason, no less important, is the economic factor, because few countries can afford to buy several tracked infantry fighting vehicles. Therefore, a wheeled carrier is a justified and often the only financially viable alternative to the modernization of transport means in the army. There are a few designs that have dominated the armoured vehicle market. Here are some of them: Dutch/German Boxer, Austrian Pandur II, Swiss vehicles of the Piranha family, French VBCI, Finnish AMV and its Polish version, Rosomak [10].

Rosomak wheeled armoured personnel carrier was a new equipment acquired for the armoured and mechanized troops of the Polish Armed Forces. The Ministry of National Defence purchased a product compliant with the 2004 specifications. The vehicle proved to meet the ballistic and blast mine protection requirements during the tests. However, it turned

out that the vehicle was insufficiently armoured for the needs of operations in Afghanistan, especially with regard to RPG attacks. Too weak armour, which failed to sufficiently protect the soldiers from gun fire, and not very effective means of communication were the main reasons for considering the withdrawal of Rosomaks from the combat mission [23].

The first modernization work on the vehicle was aimed at adapting it to perform tasks during ISAF operations. The preparation programme was carried out in two parallel paths and it provided for:

- retrofitting the vehicle in accordance with user recommendations based on the Initial Tactical and Technical Requirements regarding:
  - acoustic sniper localization system (ASLS);
  - side cameras in AMV Rosomak;
  - non-skid chains;
  - new body cover;
  - PNR-500 radio communication system;
  - KF 5800 H radio station and KOMUT 10Ta device with the necessary equipment and software;
  - FONET system provided with a portable control panel;
  - commander's panel DD9620T-10;
  - adapting the vehicle to install military GPS and AFTS;
  - cable cutting knives;
  - containers for razor wire installed on the AMVs;
  - headsets;
- additional armour based on Initial Tactical and Technical Requirements, in terms of ballistic resistance up to Level 4 according to STANAG.

Verification of the modernization work was carried out between January and April 2010[1]. The tests were passed - although after reinforcement of armour under the turret the permissible total weight (26 tonnes) was exceeded, and therefore it was necessary to eliminate some of the vehicle equipment. From that year on, all AMV combat versions directed to the Polish Military Contingent in Afghanistan were armoured and retrofitted in this way. Rosomak, despite its name, is not a typical wheeled personnel carrier. 24 vehicles, which were sent to Afghanistan, had Hitfist 30P turrets with 30 mm cannons, and thereby fulfilled the functions of an infantry fighting vehicle [2]. In addition, the vehicle had a standard protection, defined in NATO according to STANAG 4569 - for lightly armoured vehicles, it met the standards of Level 2, being resistant from all sides to strikes from automatic handguns with calibre 7.62 mm x 39 rounds from a distance of 30 m. It was also resistant to fragments of 155 mm shells exploding at a distance of 80 m from the vehicle. The vehicle crew also had a high probability of leaving unscathed in the event of a detonation under the vehicle of mines weighing up to 6 kg. In fact, a "bare" Rosomak also provides resistance to shells specified for Level 3 - 7.62 mm, but fired at higher speed from sniper rifles. In addition, on its front Rosomak had a resistance of Level 4, i.e. heavy machine guns 12.7 mm and 14.5 mm. These

[1] At the Military Institute of Engineer Technology tests were carried out on the impact of an 8 kg mine explosion (equivalent to a TM-62M mine) under the ROSOMAK front wheel. The explosion caused its destruction (and breaking off) and transfer of the mechanical stress to the structure of the vehicle shell, which affected the structure of the turret and jamming thereof. As a consequence, it was one of the main reasons for the modernization of the mechanical structure of the turret and of adjacent parts.

were usual specifications for APCs (Armoured Personnel Carriers) and IFVs (Infantry Fighting Vehicles).

In general Rosomak is not inferior to MRAP vehicles in this respect. This does not mean that they are indestructible, as there have also been irreversible losses of vehicles caused by IED explosions. As the opponent altered its tactics, which changed the type of threat, Rosomaks underwent further modifications. These led to substantial increase of weight of the vehicle: – from 22 to 27 tonnes in the case of the combat version. In a mixed patrol, consisting of MRAP vehicles, moving along Afghan wilderness, it is the Rosomaks that show the highest ability to overcome obstacles (crews emphasize the performance of the power transmission system), and provide better protection and are provided with incomparably more powerful armament. Another advantage of Rosomaks are thermal imaging cameras integrated with the gunner's sight and precise cannons that enable hitting point targets from a distance of up to 3000 m. These are the advantages that highlight the importance of AMV Rosomak (Fig. 4).

Fig. 4. Return of a joint Polish/US patrol near Miri in the Ghazni province of Afghanistan [21]

Even the most affluent armies cannot afford permanent purchases of new weapon systems, which is why a cheaper alternative is the modernization of existing resources. The cost-effect relationship is very important in modernization [3]. Therefore, any future modernization of Rosomak should cover such areas as: active defence system, deck armaments and fire control system, mine protection, chassis and body design, additional equipment, command and communications.

Vehicle survival experts emphasize that the basis is to provide the highest level of protection for the crew and soldiers depending on the requirements of the mission, even at the price of compromising other features, such as floatability [16]. Some countries have implemented (Israel – Trophy), or intend to implement active vehicle protection systems (APS). The important role of research is also emphasized, aimed at ensuring an increased survival rate of vehicles in the battlefield by improving the effectiveness of armoured guards, searching for new highly resistant materials and improving vehicle units such as: puncture resistant wheels, special design of chassis resistant to mine and IED explosions. When it comes to vehicle armour, it is best to use layered armour guards that are a combination of steel plates, composites and ceramics. Another path is to explore the use of electromagnetic or electric field against IED fuses and EFPs (Explosively Formed Projectiles).

The most common solutions aimed at increasing the degree of protection and survivability of vehicles and soldiers in the battlefield include [16]:

- light shield systems against projectiles fired from hand-held AT grenade launchers;
- seats that abate the effects of mine or IED explosion;
- light "combined" APS's;
- armoured glass of increased strength;
- solutions to improve the efficiency of vehicle wheel use - tests and finished products that ensure an increased degree of protection through the use of additional wheel inserts and tyre slip prevention systems.

7. CONCLUSIONS

The aim of the article was to present selected technical solutions in the aspect of protecting crews of military vehicles and to analyze the latest solutions and trends in the field of crew protection. The problem was illustrated by presenting the main threats to today's world, defining the types of conflicts, by presenting what equipment and armament will be adequate to face the current threats and what are the technical and technological solutions of military equipment used by the various armies in the world.

The nature of contemporary armed conflicts forces us to look for novel and more effective technological solutions that would effectively protect the crew. Many new types of vehicles have been developed and more are being designed, and many vehicles used to date are being modernized to increase crew safety. Among the emerging new vehicles are the leaders of the new generation of versatile High Mobility Multirole Wheeled Vehicles. Among others, these include the Slovak Aligator, Iveco M65 LMV, Dingo. The great advantage of these vehicles is their ability to move in very tough terrain, and for this reason they are often called off-road kings.

Based on the analyzes carried out, the following conclusions can be drawn.

1. One important aspect of designing and modernizing weapon systems is shaping them so that their operation ensures not only effective task performance, but also high survivability in the battlefield and safety of soldiers – equipment users. The professionalization of the armed forces is determined not only by expanding their size, by changing the training processes or organizational and dislocation structure, but also by proper armament and equipment.
2. Weapon systems currently used require constant improvement and change. First of all, when operations are conducted abroad, opinions about the equipment used should be obtained directly from the soldiers who use it. Each soldier should be thoroughly questioned, what factors in his/her opinion improved the level of safety and what factors negatively affected this aspect of the military operation. This would significantly reduce the number of injured soldiers in the future.
3. Considering the modification of weapon systems, it should also take into account the availability of the latest technologies, which at this stage may not always be offered by the domestic defence industry. It is important to search for strategic foreign partners in possession of advanced armament technologies and to cooperate with them, taking into account the possibility of developing national defence capabilities.

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