CREW SAFETY IMPROVEMENT IN KTO ROSOMAK VEHICLE

Abstract. The paper presents an analysis of the cases of the use of anti-tank grenade launchers where vehicles of the Polish Military Contingent in Afghanistan were involved. Methods of bombardment applied by the enemy in these cases are described. The paper discusses the results of research carried out in Poland on improving protection of vehicles against such threats. In the summary reference is made to the implemented preventive measures: modifications in the design and operation of KTO ROSOMAK aimed at improving vehicle crew safety.

Keywords: Polish Military Contingent, handheld grenade launcher, armoured personnel carrier, KTO ROSOMAK, passive armour.

1. INTRODUCTION

At present there is no threat of an open armed conflict, in which thousands of aeroplanes, tanks and soldiers would take part, and where actions would extend along hundreds of kilometres of frontline. There is a risk of outbreak of regional conflicts (Chechnya, Afghanistan, Syria) and terrorist attacks (Lebanon, Northern Ireland). In the zone of potential conflict, the main types of threat for soldiers, logistic vehicles and combat vehicles include light automatic weapons, anti-tank grenade launchers, fragmentation shells, mines, IED charges, constituting the basic weaponry of terrorist and diversionary groups operating as small subunits in rough terrain (urban infrastructure, hilly areas).

Simple design and ease of operation are the features of handheld grenade launchers (RPGs) that make them a weapon quite often used by all sides of a conflict. Their other advantages include: low cost of manufacture, small dimensions, high penetration capability in excess of 600 mm RHA\(^1\).

The article presents observations of the Polish Military Contingent (ISAF) on mission in Afghanistan of the use of handheld grenade launchers by terrorist groups and the impact thereof on technical improvements made in the Rosomak vehicle.

2. STATISTICS ON THE USE OF HANDHELD GRENADE LAUNCHERS IN THE AFGHANISTAN THEATRE OF OPERATIONS

According to data reported on the Operation Enduring Freedom site [1], in the years 2005 - 2016 the ISAF forces suffered 164 fatalities as a result of RPG use, that number constituting 4.65% of total life losses.

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\(^1\) (rolled homogenous armour – homogenous armour steel, of equivalent penetration value in homogenous steel armour determined in firing tests).

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3. ANALYSIS

3.1. Operating principle

Upon leaving the barrel, the stabilizing fins of the grenade unfold under the action of centrifugal force and resistance of air and provide stability to the launcher: Fig. 2. After the delay element burns down, a squib is ignited which activates the propelling charge of the rocket motor. Fuse becomes armed during the flight of the grenade at a distance of 2.5 to 18 m from the muzzle. Fuse arming is effected by moving a slider to a firing position, in which an electric primer detonator closes an electric circuit.

Fig. 2. a) Grenade launched from RPG-7
b) Flight of RPG head [7]
Fig. 3 shows the ignition of the rocket motor and discarding of projectile elements. It should be pointed one that much time has passed between the development of RPG-7 and that of Carl Gustaf, but the principle of operation has not changed.

![Image](image1.png) ![Image](image2.png)

**Fig. 3. Launching a projectile from an 84mm Carl Gustaf recoilless rifle** (photo by J. Ejsmont)

When the head hits the target, a piezoelectric element is compressed by a nut and contact which generates an electric charge on the electrodes of that element. When the potential difference between the electrodes attains a defined value, a spark discharge occurs in the spark gap which detonates the initiating agent in the spark gap.

### 3.2. Penetration abilities of PG-7 warhead

The penetration ability of the PG-7 warhead, determined in firing tests, ranges from 260 to 600 mm RHA. It depends on the warhead type and armour type and structure. The penetration values of the PG-7 warheads are listed in Table 1.

**Table 1. Penetration values of the PG-7 warheads** [2], [4]

<table>
<thead>
<tr>
<th>Warhead</th>
<th>PG-7V</th>
<th>PG-7VM</th>
<th>PG-7VL</th>
<th>PG-7VR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter (mm)</td>
<td>HEAT</td>
<td>85</td>
<td>70</td>
<td>93</td>
</tr>
<tr>
<td>Length (mm)</td>
<td>925</td>
<td>940</td>
<td>990</td>
<td>1635</td>
</tr>
<tr>
<td>Charge weight (kg)</td>
<td>2.2</td>
<td>2.0</td>
<td>2.6</td>
<td>4.5</td>
</tr>
<tr>
<td>Muzzle velocity (m/s)</td>
<td>120</td>
<td>140</td>
<td>112</td>
<td>150</td>
</tr>
<tr>
<td>Maximum velocity (m/s)</td>
<td>300</td>
<td>300</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Range (m)</td>
<td>500</td>
<td>500</td>
<td>300</td>
<td>200</td>
</tr>
<tr>
<td>Penetration ability (mm)</td>
<td>260</td>
<td>300-330</td>
<td>500</td>
<td>ERA+600</td>
</tr>
</tbody>
</table>

### 3.3. Penetration with a HEAT projectile

There is no one general mechanism of armour piercing by a projectile. There are only general indications resulting from the observation of projectile collisions with various types of armour.

There is a wide variety of structural design of armour, both because of various types and densities of the materials used, as well as of various combinations of layers and the thickness thereof. The functional parameter is the areal density of armour. Fig. 4 shows an example of armour penetration with a HEAT projectile.
Fig. 4. A pictorial diagram of a projectile hitting an armour plate (author’s study)

Detonation generates a pressure wave which acts on the shaped charge liner and creates a jet, an example of which is shown in Fig. 5.

Fig. 5. View of a shaped charge jet penetrating a screen plate with angle of fragments scatter inside vehicle reduced by liner layer [6]

The mass of the shaped charge jet constitutes ca. 20% of the mass of the shaped charge liner and it moves at a speed of ca. 2-3 km/s along the projectile axis. It is formed only when the mass speed gradient along the liner radius is sufficiently low not to cause liner fragmentation and sufficiently high to form the material of the shaped charge liner into proper elongated and aerodynamic shape. The remainder of the liner material moves at a relatively low speed.

After piercing the armour, the shaped charge jet behaves like a liquid, which is shown in Fig. 5. After hitting the vehicle, the pressure in the troops compartment rises rapidly to ca. 30 kPa resulting in crew injuries. The pressure rise is accompanied by temperature increase which can lead to thermal injuries of the crew members.

3.4. Armour of KTO Rosomak

The armour of the Rosomak consists of two layers: main layer made of 10 mm thick armour steel and 8 mm outer armour attached to the main layer. The strength of the outer armour, and thereby its weight, may be adapted to the user's needs. There is a void space between the layers of the armour which may be filled with a foam increasing the vehicle's displacement. The basic structure of the side armour of the vehicle includes a system presented in Table 2 and shown in Fig. 7.
Fig. 6. Lateral surface area of KTO M1 [17]

Table 2. Structure of the armour of KTO M-1 (author’s study)

<table>
<thead>
<tr>
<th>Area</th>
<th>Outer structure</th>
<th>Inclination angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Side</td>
<td>Armox 500T 10 mm</td>
<td>9°</td>
</tr>
<tr>
<td></td>
<td>Air gap 75 mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Armox 500T 10 mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Armox 590T 8 mm</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 7. View of Rosomak armour structure

Depending on armour thickness, either low-alloy or alloy low-temperature (150-220°C) tempering steel (up to 25 mm) or alloy high temperature (500-650 °C) tempering steel (up to 300 mm) is used.

Content of the main elements and mechanical properties of examples of Armox armour plates used for the construction of the armour of the Rosomak are given in Tables 3 and 4.
Table 3. Chemical composition of Armox armour steels [16]

<table>
<thead>
<tr>
<th>Steel grade:</th>
<th>Content of the elements (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C</td>
</tr>
<tr>
<td>Armox 500S</td>
<td>max. 0.30</td>
</tr>
<tr>
<td>Armox 560S</td>
<td>max. 0.37</td>
</tr>
<tr>
<td>Armox 46100</td>
<td>max. 0.32</td>
</tr>
</tbody>
</table>

Table 4. Mechanical properties of Armox steel plates [16], [15]

<table>
<thead>
<tr>
<th>Steel grade:</th>
<th>Plate thickness (mm)</th>
<th>$R_{p0.2}$ (MPa)</th>
<th>$R_m$ (MPa)</th>
<th>$A_s$ [%]</th>
<th>Impact energy (J) ISO-V-40°C</th>
<th>HB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Armox 500T</td>
<td>6, 13</td>
<td>1300</td>
<td>1500-1750</td>
<td>8</td>
<td>20</td>
<td>480-540</td>
</tr>
<tr>
<td>Armox 560T</td>
<td>up to 100</td>
<td>1300</td>
<td>1600-1900</td>
<td>7</td>
<td>15</td>
<td>530-580</td>
</tr>
<tr>
<td>Armox 440T</td>
<td>up to 50</td>
<td>1300</td>
<td>1250-1550</td>
<td>10</td>
<td>30</td>
<td>420-480</td>
</tr>
<tr>
<td>Armox 500S</td>
<td>6, 13 &gt; 13</td>
<td>1300</td>
<td>1600</td>
<td>8</td>
<td>10</td>
<td>min. 480</td>
</tr>
<tr>
<td>Armox 560S</td>
<td>up to 100</td>
<td>1500</td>
<td>1800</td>
<td>8</td>
<td>12</td>
<td>min. 450</td>
</tr>
<tr>
<td>Armox 46100</td>
<td>up to 50</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>14</td>
<td>477 – 534</td>
</tr>
</tbody>
</table>

3.5. Type of threat

The main threat encountered by the Polish Military Contingent in Afghanistan was that caused by Improvised Explosive Devices. Such charges required the preparation by Talibans of the site for planting them. The other major threat was firing of handheld grenade launchers. In this case the tactics used was "fire and forget". Firing was usually done by two or three men provided with a means of escape (motorcycles).

The preferred sites of attack were stretches of road where U-turns were made. The sites and attacks were prepared and executed at various times of day, often in the evening (at dusk) when convoys had to move using night vision systems.

The hiding places used by Talibans included the groves, old culverts, walls surrounding such structures or places. Firing was done from a distance of 80 to 150 m. The short distance was dictated by poor marksmanship.

Figs. 8 and 9 show examples of the effects of the use of handheld grenade launchers against the vehicles of the Polish Military Contingent.
Crew safety improvement in KTO ROSOMAK vehicle

Fig. 8. Cougar 4x4 MRAP fired at from an antitank grenade launcher

Fig. 9. View of a Rosomak vehicle penetrated by a projectile from a handheld grenade launcher (vehicle version prior to modification)
Injuries suffered by crew members of vehicles assaulted with handheld antitank grenade launchers included hearing and eyesight impairment, orthopaedic injuries of the lower and upper limbs, and thermal burns.

4. COUNTERMEASURES

After the deployment of the contingent in Afghanistan, information on the threats caused by RPGs and shaped charge projectiles started to flow in.

The first attempts to improve vehicle resistance made in 2008 and 2009 consisted in on-site mounting of additional ballistic protection, which is shown in Fig. 10. The next stage in safety improvement was the mounting of side panels (called grills). This indeed improved the level of protection, the permissible weight of the vehicles, however, was exceeded.

![Fig. 10. a) Additional armour installed during the 5th turn of the contingent in 2009 b) "Grill" type additional armour [11]](image)

At the turn of 2009 and 2010 efforts were taken in Poland to strengthen the ballistic protection of the vehicle by equipping Rosomak vehicles with protection screens against shaped ordnance. Fig. 11a shows a design from RUAG Land Systems AG of Switzerland, Fig. 11b shows a design from Qinetiq of USA.

![Fig. 11. a) Modified Rosomak M1 with LASSO protection system from RUAG, b) Rosomak M-1 with add-on armour and lightweight screen system](image)
Eventually Rosomak vehicles were provided with Qinetiq protective screens shown in Fig. 11b. The set consists of 10 panels with a total weight of about 350 kg. The panels are set up on a frame spaced from the side surface of the hull by 25 cm. The panels are fastened to the hull by means of brackets screwed to the hull, as shown in Fig. 12. The installation of the add-on members made the vehicle wider by about 70 cm which, however, has not affected the functionality of the vehicle, including its air and rail transportability. If smaller transport aeroplanes are used, the add-on members may be easily dismantled.

![Fig. 12. Installation of lightweight protective screens on a Rosomak vehicle](image)

Lightweight screens are of simple design and are easy to fabricate and provide protection against shaped charge projectiles from handheld antitank grenade launchers. Its low weight and lack of solutions involving explosives made the system widespread in a number of armies across the world.

The operating principle is identical for both net-type armours shown in Fig. 11 as well as for bar- or truss-type armours shown in Fig. 10.

When the warhead reaches the net, an interaction occurs between metal elements and strings. The warhead of the projectile becomes damaged, the shaped charge liner undergoes deformation, the housing is damaged and the explosive is fragmented. In this case the strings act as bars in conventional bar armours.

![Fig. 13. Net operating principle](image)

Fig. 14 shows a projectile hitting the protective net, and Fig. 15 shows a projectile penetrating a bar armour and illustrates how the RPG is incapacitated.
Fig. 14. A PG-7V projectile hitting a conventional spaced armour, basic armour; photo AmSafe [8]

Fig. 15. a) Initial contact between projectile and armour, b) Warhead penetrating the bars [6]

5. CONCLUSIONS

After the deployment of the KTO M1 vehicle in the theatre of operations, numerous modifications were implemented in the vehicle in accordance with the suggestions from the Operational Command of the Polish Armed Forces and from the Office of the Defence Minister Representative, Director of the Programme for the Introduction of Armoured Personnel Carriers and Antitank Guided Missiles into Service in the Polish Armed Forces.

The following modifications were made:
- provision of additional armour (Fig. 16);
- purchase of protective nets (Fig. 17);
- improved ballistic protection of driver's hatch and side panels on turret (Fig. 18).
Crew safety improvement in KTO ROSOMAK vehicle

a)  

![Image of Rosomak after 14.5 mm calibre shelling tests](image1)

b)  

![Image of add-on armour plate after detonation of a PG-7V antitank grenade](image2)

Fig. 16. a) Rosomak after 14.5 mm calibre shelling tests  
b) add-on armour plate after detonation of a PG-7V antitank grenade [11]

![Image of Rosomak M1M vehicle](image3)

Fig. 17. Rosomak M1M vehicle [20]

![Image of additional armour modifications](image4)

Fig. 18. Additional armour modifications made by Cenrex sp. z o.o. and MIKANIT [12]

The result of the efforts of the Office of the Director of the Programme for the Introduction of Armoured Personnel Carriers and Antitank Guided Missiles into Service in the Polish Armed Forces was that conclusions drawn from the incidents were closely studied and appropriate modifications were made in the Modernization Programme of the Armed Forces.
The implemented changes in the design were made possible due to close collaboration of research units and institutes and the armaments industry.

6. REFERENCES


