The analysis of main requirements for means of transportation in technical recovery of specialized heavy vehicles

INTRODUCTION

Among the differentiated means of transportation in the transportation system there are special vehicles. They are particularly numerous in the military, where the majority of means of transportations are special vehicles or vehicles used for special purposed [9]. These vehicles are subject to a range of threats [11], among which technical status and logistic support are to be mentioned. The influence of these threats results in the fact that effective operations in the scope of technical recovery are necessary.

1. TECHNICAL RECOVERY OF SPECIAL VEHICLES

In the Polish Armed Forces as per applicable provisions on logistics [4] the technical recovery is one of the elements of the process known as technical evacuation. Technical evacuation is a forced movement of unusable or left military equipment from the threat zone to another place or from unnatural positions (e.g. rollover) into the use position. The evacuation can be a primary process and include pulling-out, object transfer to the nearest enemy-free zone or a secondary process, being the follow-up of evacuation to the target destination. In the evacuation process the references [1, 6] provide the parameter of evacuability. The parameter reflects the evacuation difficulty grade for a given object and is the resultant of its physical properties, position and ground characteristics. The physical properties are: weight, structural design and external dimensions. The ground characteristics is its relief and compactness. The position is the change in vehicle position towards the position during normal operation. The evacuability is the source of main requirements for evacuation vehicles. The task of technical recovery is to remove the immobilized military vehicle with crew from the enemy threat. Therefore there are subsequent requirements related to the protection of both crews and the dimensions of crew compartment of the towing vehicle.

The evacuation tasks of the recovery can be implemented by pulling-out, extracting or positioning [3], and then by towing, semi-transport and transport. The performance of each methods determines the requirements for equipment, structural design and the power of the towing vehicle. Subsequent requirements are related to the technical characteristics of the towing vehicle and its structural design. They result from the towing vehicle arrival time and evacuation time. However the calculation of evacuation capabilities assumes the average velocities of recovery vehicles [3], which are approx. 30-35 k/h on hardened roads and 20-25 km/h on non-hardened ones. The main requirements pertain then to the vehicle technical characteristics, recovery vehicle structural design and power available to perform needed work.

2. REQUIREMENTS FOR TECHNICAL CHARACTERISTICS

The selection methods for necessary technical characteristics consist in their specification and description of quantity characteristics – this allows the equipment administrator to professionally assess offers and take the decision.

The basic characteristics includes:

- loading capacity;
- maximum velocity and road slope at $V_{\text{max}}$;
– running gear of the recovery vehicle and trailer;
– pressure on towing recovery and trailer axles;
– tire characteristics;
– movement stability;
– turn diameter;
– cab characteristics and ergonomics;
– ballistic and ant-mine protection.

The basic criteria for the movement property assessment is the capability of the recovery vehicle with damaged vehicle to move with the required average velocity on non-hardened roads. The nominal engine power for the recovery vehicle of certain weight (60 kN) on average is set according to that criterion.

The calculation formula for the needed total unit power and partial powers depending on the velocity is defined as below:

\[ N_j = \frac{N_f}{G} + \frac{N_p}{G} + \frac{N_H}{G} \quad (1) \]

where:
\[ \frac{N_f}{G} \] – necessary unit power to overcome the turning resistance;
\[ \frac{N_p}{G} \] – unit power of air resistance;
\[ \frac{N_H}{G} \] – unit power of towing resistance.

3. SPECIFICATION OF EVACUATION AND TECHNICAL RECOVERY VEHICLES

Armoured evacuation and technical recovery vehicles are tracked or wheeled vehicles built on the basis of tanks or armoured combat vehicles (ACV), intended to carry out recovery missions, such as:

– using a winch to pull out tanks or ACV that got bogged down in mud, sand or some other soft ground;
– to tow away a damaged vehicle to a place, from which it can be evacuated to its repair point; to perform simple repairs of the above types of vehicles under the conditions of combat operations. [10]

The main tasks of armoured heavy evacuation and technical recovery vehicles include:

– evacuation of vehicles, incapable of moving independently due to enemy operation, mechanical damage or bogging down in the ground;
– towing of damaged vehicles to their repair point or point of loading onto a transport trailer and their transport to the place where the repair is possible;
– replacement of basic subcomponents of damaged vehicles, such as engine or turret;
– preparation of repair works using tool set at hand;
– transport of spare parts;
– welding works;
– pumping out fuel from damaged vehicles and pumping over to operable vehicles;
– earthworks using blade, such as ground levelling, trenches, back-filling of craters or removal of debris (embers);
– removal of obstacles (fallen trees, wrecks, etc.);
– evacuation and first aid for the injured.

Usually these are four- or five-axle vehicles, with total weight between 30 and 40 tonnes, providing good mobility both on hardened roads and on the ground. They are particularly used to transport large and heavy loads (in pallets, containers or bulk). [10]

According to numerous operational consideration, tactical evacuation vehicles should be among the first ones from the new family of technical vehicles, introduced as army equipment. As per the definition and the development of that type, tactical evacuation and technical recovery vehicles, built on the basis of this family of high loading capacity tactical vehicles, should:
have at least the same level of mobility (both on hardened roads and on the ground) as the vehicles the operation of which is to be secured;

– be capable of pulling out the damaged vehicle to the place where it can be evacuated to the repair point;

– be capable of pulling out independently, using winch, a vehicle that bogged down in mud, sand or other soft ground, without damaging it;

– be equipped with a tool set allowing for simple repairs.

Apart from the above features, the equipment used in this vehicle should ensure that all operations related to vehicles coupling while pulling-out and towing are as simple and rapid as possible in order to minimize the enemy firing exposure for the crew.

If the tactical evacuation and technical recovery vehicle is equipped with rotary crane, it can be additionally used to reload containers, pallets, chassis and weapon system modules, both in the field and in warehouses (lifting engines or turrets, etc.). The contemporary heavy tactical evacuation and technical recovery vehicle needs to be an optimal combination of proper chassis and proper evacuation equipment.

Heavy tactical evacuation and technical recovery vehicles are built on the chassis of high loading capacity tactical vehicles, usually with 8x8 running gear. In each analysed case, these vehicles are one of the elements of the family of high loading capacity tactical vehicles. The evacuation equipment of these vehicles consists of main winch, arm or towing devices, crane devices. Additionally there are supporting devices such as auxiliary winch, anchor device and stabilizers. There two types of crane devices used for reloading in heavy tactical evacuation and technical recovery vehicles – cranes and folded cranes. The used cranes have the lifting capacity of $150 \div 153$ kN, whereas the folded cranes – from 65 to 125 kN. The following types of devices are used to anchor the evacuation vehicles: independent anchors pulled out hydraulically or manually, blade mounted to the vehicle rear, replaceable anchors attached to stabilizers. [2, 5, 10]

The rule is that as a standard the heavy tactical evacuation and technical recovery vehicles are equipped with winches for self-evacuation with the towing power of 80 to 100 kN.

The additional equipment of these vehicles are:

– adapter sets to tow different vehicle types;
– sets for welding works;
– tools sets for simple repairs.

4. DOMESTIC SOLUTIONS

As part of specific project of the Ministry of Science and Higher Education no. 356/BO/1 a domestic solution was developed for the wheeled evacuation and technical recovery vehicle – KWZT "Mamut". Its characteristics, equipment and general structural design result from the need to meet the main, previously determined requirements.

Fig. 1 Wheeled evacuation and technical recovery vehicle. Source: WITPiS materials
Tab. 1. Basic technical parameters [7]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mamut</th>
</tr>
</thead>
<tbody>
<tr>
<td>Origin:</td>
<td>Poland</td>
</tr>
<tr>
<td>Cabin armour Level</td>
<td>2</td>
</tr>
<tr>
<td>Base vehicle</td>
<td>Tatra 7Z0R9T-37A</td>
</tr>
<tr>
<td>Running gear</td>
<td>8x8</td>
</tr>
<tr>
<td>Cab</td>
<td>4</td>
</tr>
<tr>
<td>Total weight</td>
<td>35 tonnes</td>
</tr>
<tr>
<td>Length</td>
<td>Without blade</td>
</tr>
<tr>
<td>Width</td>
<td>2.55 m</td>
</tr>
<tr>
<td>Height</td>
<td>To the cab</td>
</tr>
<tr>
<td>Clearance</td>
<td>0.39 m</td>
</tr>
<tr>
<td>Wheelbase</td>
<td>1,950 + 3,660 + 1,450 mm</td>
</tr>
<tr>
<td>Entry/descent angle</td>
<td>45° / without blade</td>
</tr>
<tr>
<td>Maximum velocity</td>
<td>90 km/h</td>
</tr>
<tr>
<td>Fording</td>
<td>1.20 m without preparation</td>
</tr>
<tr>
<td>Engine power</td>
<td>440 kW / 12.5 kW/t</td>
</tr>
<tr>
<td>Tire size</td>
<td>16.00 R20</td>
</tr>
<tr>
<td>Crane</td>
<td>12,000 kg per 3.5 m  = 43.9 Tm</td>
</tr>
<tr>
<td>Main winch</td>
<td>2x 28 tonnes 100 m</td>
</tr>
</tbody>
</table>

A towing extension system, i.e. a device to lift and fix the towed vehicles, is mounted to the rear frame. It consists of two fixed vertical poles with rectangular cross-section, permanently connected with the auxiliary frame. Inside the fixed poles there are movable poles, which by means of crossbars in the top part are lifted by a pair of hydraulic servomotors. In the top part the poles are connected with a special bracket with mounted support rollers to hold the lines of the main winches. A towing extension is mounted to the movable poles on special brackets, inside the movable poles there are servomotors mounted to fold the towing extensions to the transport position (by 90° upwards). Hydraulic lifting and towing device ensures safe towing of vehicles with the total weight exceeding 26 tonnes on the ground with the velocity of 20 km/h and on hardened road with the velocity of 35 km/h.

The construction of the towing extension does not eliminate the factory mounted towing eye.

4.1. Unique MAMUT's features

The construction features of particular interest that distinguish the domestic project are listed below:

- 440 kW (585 BHP) power engine of military line, not requiring the use of any additional substances (Ad blue);
- spatial (closed) vehicle frame instead of standard one based on channel bars, better vehicle rigidity and strength to overloads resulting from towing on the ground;
- independent suspension of all axles;
- single tires (16.00 R20) with Run Flat inserts on all axles (similar constructions are forced to use twin tires on rear axles, what limit the ground capabilities);
- the possibility to have the blade installed in the vehicle front to re-open the crossings, temporary back-filling of road gaps (other vehicles do not have such ability, in particular when maintaining the attack angle of min. 21°), with steering system from the driver's seat;
- the possibility to use the main winches to work from the vehicle rear and one from vehicle front (similar constructions can use only the rearwards winch);
- attack angle without blade mounted 45°;
- the vehicle is equipped with two winches with integrated layer and additionally with line pusher (these are only winches equipped with layer preventing rope tangling on the drum);
– the vehicle is equipped with two fuel tanks (2x320L), armoured to Level 2, according to STANAG 4569 (similar construction do not have such solution);
– the use of the biggest transport crane in such category of (armoured) vehicles [43.0 Tm] without losing the ability for railway transport (upon earlier preparation);
– a 4-person cabin armoured to Level 2 according to STANAg 4569 and as the only among that vehicle type – tested by a Polish research institute;
– the vehicle is equipped with usable roof over the winches, adjusted to transport the specialized equipment and safe movement inside the vehicle;
– capable of fording without preparation – 1.2 m;
– specific design of the vehicle structure, ensuring relatively low vehicle height and therefore low positioned centre of gravity – such design ensures high vehicle stability, especially during works with main winches;
– This is the only vehicle that uses tow-rod with original vehicle tow seat (capable of towing vehicles with DMC > 26 tonnes) without the need to use adapters or any other solutions;
– capable to run on a common battlefield fuel F-34;
– thanks to the use of equipment mounted in the vehicle (front blade, rear spade lugs) there is a possibility to lift the whole vehicle, e.g. to change tire or make small repairs.

The remaining distinctive features:
– central tire inflection system (CTIS) for all wheels, operated from the cabin;
– independent heating and air-conditioning system;
– Automatic Drive Management (ADM);
– cabin equipped with filter and ventilation system in case of ABC weapon attack;
– cabin equipped with roof hatch fit for mounting weapons;
– range road over 650 km;
– it has auxiliary evacuation equipment: double block with anchoring handle, thimbles, shackles, adapted to evacuate all types of Armed Forces vehicles, as well as NATO army vehicles, as per STANAG 4019;
– possibility to control the work of both winches at the same time by single operator;
– the vehicle has manual control over the towing device, winches and the crane from single desktop of operator seat and standard radio-remote control from the distance of min. 50 m of the vehicle contour;
– In the rear part of the middle frame, there are shields of support spade lugs, hydraulically extended; the spade lugs are terminated with tooth blades, allowing for punching into the ground and effectively immobilizing the vehicle; when using the spade lugs as support on the asphalt their blades are shielded with covers to prevent surface against damage. [10]

5. COMPARISON WITH OTHER DESIGNS

For the purposes of comparison analysis the table presents the main parameters of technical characteristic of the domestic technical evacuation vehicles as opposed to global constructions.

| Tab. 2. Selected technical data of heavy technical evacuation vehicles [7] |
|-----------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| **Parameter**               | **Renault Kerax BKF30.40** | **FAUN BKF30.40**        | **Oshkosh M984A1**       | **TATRA RV-20**          | **MAN HX-32.440 8x8 BB** | **KWZT Mamut**           |
| **Origin:**                 | France                   | Germany                  | USA                      | SAS The Czech Republic   | Hungary                  | Poland                   |
| **Cabin armour**            | n/a                      | n/a                      | Level 2                  | n/a                      | Level 2                  |                          |
| **Base vehicle**            | Kerax 385.40             | MAN 32.422 VFAEG         | Oshkosh                  | TATRA T816               | MAN HX-32.440 8x8 BB     | Tatra 7Z0R9T-37A          |
| **Running gear**            | 8x4                      | 8x8                      | 8x8                      | 8x8                      | 8x8                      | 8x8                      |
| **Cab**                     | 1+4                      | 1+1                      | 1+1                      | 1+3                      | 3                        | 4                        |
| **Total weight**            | 32 t in a set 65 t       | 29.5 t                   | 45.36 t                  | 32.315 t                 | 36 t in a set 65 t       | 35 tonnes in a set 70 t  |
| **Length**                  | 10.15 m                  | 9.957 m                  | 12.588 m                 | 11.245 m                 |                          |                          |
At present at the military market of technical evacuation vehicles the most modern solution has Mercedes Benz with their Bison construction. Both chassis are compared in Table no. 3.

**Tab. 3. Comparison of KWZT and MB Bison [7]**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Tatra 7Z0R9T-37A</th>
<th>Mercedes Benz 1451 AK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cab:</td>
<td>4 persons armoured to Level 2 according to STANAG 4569</td>
<td>2 persons armoured to Level 4b</td>
</tr>
<tr>
<td>Engine:</td>
<td>DEUTZ TCD 2015 V08</td>
<td>OM 502 LA</td>
</tr>
<tr>
<td>Power:</td>
<td>440 kW (585 BHP)</td>
<td>375 kW (510 hp)</td>
</tr>
<tr>
<td>Exhaust norm</td>
<td>Euro 3</td>
<td>Euro 3 with the need to use Ad blue</td>
</tr>
<tr>
<td>Max. moment</td>
<td>2,720 Nm at 1,400 RPM</td>
<td>2,400 Nm at 1,080 RPM</td>
</tr>
<tr>
<td>Fuel tanks</td>
<td>2x 320L, armoured to Level 2 according to STANAG 4569</td>
<td>600L non-armoured</td>
</tr>
<tr>
<td>Suspension</td>
<td>independent (front – air, rear – air + parabolic springs)</td>
<td>no data</td>
</tr>
<tr>
<td>Drives</td>
<td>8x8</td>
<td>8x8</td>
</tr>
<tr>
<td>Tires</td>
<td>16.00 R20</td>
<td>14.00 R20</td>
</tr>
<tr>
<td>Width</td>
<td>2,500 mm</td>
<td>2,800 mm</td>
</tr>
<tr>
<td>Fording depth</td>
<td>1,220 mm</td>
<td>750 mm</td>
</tr>
</tbody>
</table>
CONCLUSIONS

At present in the military transportation system evacuation means, including technical recovery, play an important role. The special functional properties, necessary to perform technical recovery tasks, influence the main technical parameters. Making account of them significantly influences the vehicle construction, technical characteristics and equipment. The comprehensive approach to the task implementation led to, among others, successful construction of domestic evacuation and technical recovery vehicle. The research process, the new vehicle is subject to, allowed to determine the potential for evacuation capabilities. Due to utility nature of the research results the methodology included mainly functional testing. The existing experience indicate clearly that the "evacuation susceptibility" should be accounted for at the conception work phase and favourable mechanic energy should be ensured, the source of which is the drive unit.

Abstract

The article presents the position of technical rescue in the transport system of military special vehicles. Technical rescue is associated closely with the evacuation and its component. With respect to vehicles engaged in emergency features put special requirements. The main requirements were analyzed in this article. Also presented national solutions in this regard.

Analiza głównych wymagań w odniesieniu do środków transportu w ratownictwie technicznym ciężkich pojazdów specjalnych

Streszczenie

W artykule przedstawiono umiejscowienie ratownictwa technicznego w systemie transportowym militarnych pojazdów specjalnych. Ratownictwo techniczne jest związane ścisłe z ewakuacją i jest jej elementem składowym. W odniesieniu do pojazdów wykonujących funkcje ratownictwa istotne są uwzględnienie "susceptibility" ewakuacji. W niniejszym artykule przedstawiono także krajowe rozwiązania w tym zakresie.

REFERENCES

9. Rozporządzenie MON i SWiA z 9 czerwca 2005 r. w sprawie dopuszczenia do ruchu pojazdów specjalnych i pojazdów używanych do celów specjalnych. [The Ordinance of MON and SWiA of 9 June 2005 on road permit for special vehicles and vehicles used for special purposes]