Abstract: The article discusses topics related to the research of air transport susceptibility of military vehicles. This type of research is carried out in the Vehicle Research Laboratory at the Military Institute of Armoured and Automotive Technology in Sulejówek. The authors undertook a review of normative documents in the field of air transportability of military vehicles. On the basis of the review, an analysis of the current technical requirements in the aspect of the strength of transport nodes was made. The results of the analysis of documents are presented in the form of a transparent table. The article presents the problem of strength tests of transport nodes. The authors also presented the test method, which is accredited by the Military Centre for Standardization, Quality and Codification. The article presents the results of preliminary tests of transport hooks carried out for the Honker vehicle and the results of tests of transport catches of the Heavy Wheeled Evacuation and Technical Rescue Vehicle (CKPEiRT) developed at ROSOMAK SA. CKPEiRT is an 8x8 vehicle with high payload, increased mobility, intended primarily for the evacuation of ROSOMAK wheeled armored personnel carriers. The CKPEiRT vehicle is characterized by an armoured cabin and the possibility of transporting four crew members. The results of the tests confirmed the fulfilment of requirements by the tested vehicle with respect to the strength of transport nodes.

Keywords: transportability, special vehicle, strength of transport nodes

1. INTRODUCTION

In the article, the authors presented the problem of assessing the transportability of special vehicles in the aspect of the strength of transport nodes. The problem is presented on the example of the Heavy Wheeled Evacuation and Technical Rescue Vehicle developed in ROSOMAK SA. It is an 8x8 vehicle with high payload, increased mobility. It is equipped
with a four-person armored cabin. The vehicle has the option of towing wheeled vehicles with a total weight of up to 26 tons.

2. RESEARCH PROBLEM AND RESEARCH METHOD

2.1. RESEARCH PROBLEM

As part of the work, the scope of conducted research on the adaptation of a vehicle to air transport together with the research method was presented. The authors also presented reference documents regulating the above research: ATTLA – Air Transportability Test Loading Activity, MIL-STD-209K – Interface standard for lifting and tie down provisions oraz STANAG 3548, STANAG 4300, STANAG 4062. The above documents were analysed and differences were presented.

Strength test of the transport catches

The requirements for transport hooks can be found in the following normative documents [1–8]:
- ATTLA - Air Transportability Test Loading Activity,
- MIL-STD-209K – Interface standard for lifting and tie down provisions,
- STANAG 3548 – Tie down fittings on air transported and air dropped equipment and fixed wing aircraft,
- STANAG 4300 – Restraint of Cargo in Fixed Wing Aircraft,

<table>
<thead>
<tr>
<th>Dokument normatywny</th>
<th>Wymagana wytrzymałość na przeciążenia</th>
<th>Rodzaj transportu</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATTLA STANAG 3548 (STANAG 4300)</td>
<td>3 g in the forward direction, 1.5 g in the transverse and backward direction, 2 g in the vertical direction upwards, 4.5 g in the vertical direction downwards.</td>
<td>air</td>
</tr>
<tr>
<td>STANAG 4062</td>
<td>4 g in the longitudinal direction 1.5 g in the transverse direction 2 g in the vertical direction upwards,</td>
<td>sea road railway</td>
</tr>
<tr>
<td>MIL-STD-209K</td>
<td></td>
<td>all types of transport</td>
</tr>
</tbody>
</table>

Among the NATO member countries, undoubtedly the largest role is played by the aviation of the United States of America. In addition, other armies of states belonging to NATO, in the medium and heavy aircraft category, use American production equipment. The most common are C130 Hercules, and C17 Globmaster. In order to be able to
transport military equipment with USAF aircrafts, it must pass certification for compliance with the requirements of the ATTLA (Air Transportability Loading Agency). The certificate applies to a specific type of aircraft. The requirements of ATTLA and STANAG 4300 are the same and relate to fixing the vehicle in the aircraft (selection of the amount and strength of the stays). The consequence of those requirements is the amount and strength of the transport hooks. Vehicles are also transported overland, oversea and by rail. Requirements for the vehicle in sea and rail transport are specified in STANAG 4062. STANAG 4062 Requirements are stricter and their fulfilment means that also ATTLA and STANAG 4300 requirements are satisfied. MIL-STD-209K Standard has the same requirements for hooks regardless of transport type, and they are the same as the STANAG 4062. You can see based on the above mentioned requirements, that they represent a big construction problem, which should be taken into consideration when designing the vehicle. It is even more difficult to adapt to the civil undercarriage, because transport hooks that have to transfer such heavy loads must be attached to the vehicle's load-bearing structure, capable of transferring large loads. In the case of truck and heavy duty vehicles, it is the chassis frame. In the vehicle, the frame is usually used to fasten numerous elements of the car's system. This causes a problem with the placing of hooks, because in addition to issues related to strength, access to the hooks is also important, and the possibility of assembling the stays at appropriate angles.

For special vehicles, like Heavy Wheeled Evacuation and Technical Rescue Vehicle, an additional difficulty was a complicated rescue construction. Limited access to the frame, and a relatively high weight centre which has been included in the design calculations during developing of the system by EC Engineering subcontractor ROSOMAK SA, also caused the need to place additional holders on the elements of the construction. This was preceded by obtaining the consent of sub-suppliers of elements of specialist equipment (including crane and boom of CARGOTEC) and additional calculations of FEM. During the calculations, not only the total strength value and the strength of a single point were taken into account, but the correct distribution of loads on a given vehicle element. A large number of attachment points also allows not only to evenly distribute the fixing forces on the mounted vehicle, but also to use a large number of fastening ropes to the floor of the transport platform, which is particularly important in aircraft because of the light and spatial constructions of the aircraft chassis.

Fig. 1. Rear view of the vehicle's longitudinal mounting points [13]
The following Figures 2–3 show examples of testing the transport hooks for compliance with the MIL-STD-209K standard - Interface standard for lifting and tie down provisions. Figure 3 shows the test result for a load of 150,000 lbs, the test was discontinued after reaching 147,000 lbs. The following drawings enable to visualize the amount of loads to which transport hooks are subjected and the resulting constructional problems.

Fig. 2. Testing of transport hooks for compliance with the MIL-STD-209K standard [12]

Fig. 3. Testing of transport hooks for compliance with the MIL-STD-209K standard [12]

It should also be stressed that regardless of the elaborated design of the fastening system, the instructions for use are critical when fixing the vehicle. It is an important document for both the vehicle crew and the service of, for example, an aircraft. It specifies the permissible loads that can be imposed on individual nodes, intermediate elements (e.g. shackles) necessary for use, as well as the range of angles at which ropes can be guided. It also indicates additional activities that must be carried out before transporting the vehicle. It should be emphasized that the fastening points used by the manufacturers of the basic chassis protect only to a limited extent the requirements of, especially, air transport. Their use is also dependent on the type of vehicle, the final weight of the vehicle and its distribution on the axles of the vehicle.
2.2. RESEARCH METHODOLOGY

The study of the adaptation of special vehicles to air transport, including the checking of the strength of transport nodes, consists of the following stages:
- checking the operational documentation in the field of vehicle preparation for air, rail, road and water transport,
- checking the possibility of loading the vehicle to the cargo space of the means of transport,
- checking the strength of transport hooks and the construction environment using:
  o strength test on a test bench
  o calculation method (analysis of FEM calculations),
  o a mixed method (strength and computational) in the case when the safety of the structure goes beyond the scope of elastic deformation.

3. RESULTS

As part of the work, the results of the tests of the strength of the transport hooks for the Heavy Wheeled Evacuation and Technical Rescue Vehicle on the Scania chassis were shown. The results of air transport adaptation tests on the example of Jelcz, Honker and CKPEiRT vehicles are presented below.
3.1. CHECKING THE POSSIBILITY OF LOADING THE VEHICLE TO THE CARGO SPACE OF THE MEANS OF TRANSPORT

The example of air transport shows the possibility of loading the Jelcz lorry and the single-axle trailer into the Hercules C-130E aircraft (Fig. 6). This check consists of a practical test of loading the tested vehicle into the vehicle's cargo space.

Fig. 6. View of the loading of the Jelcz car and single-axle trailer to the C-130E [7, 9]

3.2. PRELIMINARY RESEARCH

A post-accident Honker vehicle was used for preliminary tests. The hook was tested for resistance to vertical, lateral and longitudinal force (Fig. 7) until the yield point is exceeded.

The force recorder with a force transducer and a special test stand were used to measure the force. An exemplary diagram of changes in the force values during the node load test is shown in figure 8. Based on the analysis of the forces, it can be concluded that there was a permanent deformation of the transport hook.

Fig. 7. A view of the strength test of the transport hook (No. 6) for vertical, transverse and longitudinal loads
3.3. CKPEiRT VEHICLE TESTS

The strength tests of the transport hooks have been carried out for selected hooks (fig. 10–13). Test loads as well as their number and direction have been determined on the basis of the document “CKPEiRT Vehicle fastening system - FEM Calculation, ECE-A- 18002, Issue 1.1”. Each selected hook was subjected to the load for at least 6s.

Table 2 presents the nominal test loads and the instantaneous maximum loads for selected transport hooks.

<table>
<thead>
<tr>
<th>Hook number</th>
<th>Fx [daN] forward **</th>
<th>Fx [daN] backward **</th>
<th>Fy [daN] transverse</th>
<th>Fz [daN] downward **</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value Nom.</td>
<td>Max value</td>
<td>Value Nom.</td>
<td>Max value</td>
<td>Value Nom.</td>
</tr>
<tr>
<td>2</td>
<td>14600</td>
<td>14722</td>
<td>8600</td>
<td>8625</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>6500</td>
<td>6701</td>
<td>4600</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td>7000</td>
</tr>
</tbody>
</table>

*) - marking of the hook in accordance with the “ CKPEiRT-Vehicle Fastening System -MES, ECE-A- 18002, Issue 1.1"

**) - longitudinal test load “Fx forward”, corresponds to the load of the hook with a force corresponding to an acceleration of 4 g directed backwards.
- longitudinal test load “Fx backward”, corresponds to the load of the hook with a force corresponding to acceleration of 4 g directed forwards.
- vertical test load “Fz downward”, corresponds to the load of the hook with a force corresponding to the acceleration of 2g directed upwards.
Fig. 9. A view of the strength test of the front transport hook (No. 2) for longitudinal and transverse loads

Fig. 10. View of the strength test of the front transport hook (No. 2) for vertical load and side transport hook (No. 3) for lateral load

Fig. 11. View of the strength test of the side transport hook (No. 3) for vertical load and side transport hook (No. 4) for longitudinal load

Fig. 12. A view of the strength test of the side transport hook (No. 6) for vertical and transverse loads
Fig. 13. The course of changes in the force values during the transport node load test

On the basis of the tests carried out as well as visual inspection and analysis of force records, no damage or permanent deformations were found in the tested fasteners and their structural environment (vehicle frame and fasteners).

4. CONCLUSIONS AND SUMMARY

The tests carried out showed both correctness of the test method and adequate strength of transport points developed for the needs of transporting the Heavy Wheeled Evacuation and Technical Rescue Vehicle produced in ROSOMAK SA. Practical tests also confirmed the correctness of FEM calculations performed by EC Engineering. Positive test results of the fastening system, especially in the field of very stringent air transport requirements, carried out at the Military Institute of Armoured and Automotive Technology, allow the vehicle to be quickly moved to foreign missions using both domestic and allied aircrafts, and the use of CKPEiRT as logistic security for military units.

References

1. ATTLA - Air Transportability Test Loading Activity.
3. STANAG 3548 – Tie down fittings on air transported and air dropped equipment and fixed wing aircraft.
4. STANAG 4300 – Restraint of Cargo in Fixed Wing Aircraft.
5. STANAG 4062 – Sling and Tie Down Facilities for Lifting and Tie Down Military Equipment for movement by Land and See.
PROBLEMATYKA OCENY TRANSPORTOWALNOŚCI POJAZDÓW SPECJALNYCH W ASPEKcie WYTRZYMAŁOŚCI WĘZŁóW TRANSPORTOWYCH

Streszczenie: W artykule podjęto tematykę związaną z badaniami lotniczej podatności transportowej pojazdów wojskowych. Tego typu badania prowadzone są w Laboratorium Badań Pojazdów w Wojskowym Instytucie Techniki Pancernie i Samochodowej w Sulejówku. Autorzy podjęli się przeglądu dokumentów normatywnych w zakresie lotniczej transportowalności pojazdów wojskowych. Na podstawie przeglądu wykonano analizę aktualnych wymagań technicznych w aspekcie wytrzymałości węzłów transportowych. Wyniki analizy dokumentów przedstawiono w formie przejrzystej tabeli. W artykule przedstawiono problematykę badań wytrzymałości węzłów transportowych. Autorzy również przedstawili metodę badania, która jest akredytowana przez Wojskowe Centrum Normalizacji, Jakości i Kodyfikacji. W artykule zaprezentowano wyniki badań wstępnych zaczepek transportowych przeprowadzonych dla pojazdu Honker oraz wyniki badań zaczepek transportowych Ciężkiego Kołowego Pojazdu Ekwakuacji i Ratownictwa Technicznego (CKPEiRT) opracowanego w ROSOMAK SA. CKPEiRT jest pojazdem 8x8 dużej ładowności, powiększonej mobilności przeznaczony przede wszystkim do ewakuacji kołowych transporterów opancerzonych ROSOMAK. Pojazd CKPEiRT charakteryzuje się opancerzoną kabiną oraz możliwością transportu czterech członków załogi. Wynika badań potwierdziły spełnienie wymagań przez badany pojazd w zakresie wytrzymałości węzłów transportowych.

Słowa kluczowe: transportowalność, pojazd specjalny, wytrzymałość węzłów transportowych