ISSN: 1231-4005
e-ISSN: 2354-0133
DOI: 10.5604/12314005.1217272

NUMERICAL AND EXPERIMENTAL RESEARCH ON THE DYNAMIC LOADS IN MILITARY VEHICLES

Piotr Rybak, Wacław Borkowski, Józef Wysocki

Military University of Technology
Kaliskiego Street 2, 00-908 Warsaw, Poland
tel.: +48 261 839531, fax: +48 261 837370
e-mail: piotr.rybak@wat.edu.pl, wacław.borkowski@wat.edu.pl
jozef.wysocki@wat.edu.pl

Abstract

The work presents the fragments of research on the dynamic loads acting on selected military vehicles. Designing new armoured vehicles or introducing modifications is preceded by model tests carried out under various conditions, analysing the effect of dynamic loads which may result during the use of the vehicle, e.g. due to the roughness of the road, firing, IED explosions or the vehicle being hit by a shell. The main purpose of conducting model research and verifying their findings in experimental research is to improve the effectiveness and safety of operation of systems and installations of military vehicles, increase the dynamics of the movement, improve the protection and ensure that the crew is not killed. Among the used models of military vehicles, discrete models are applied, formulated in the adjusted Lagrange description, as well as the models based on the fine element method for highly nonlinear problems and forces acting for a very short time. Due to the unique selection of military equipment, the methods of calculation and analysis of model research (simulations) and experimental research presented in the work are considered qualitative rather than quantitative.

Keywords: *military vehicle, armoured vehicle, loads, research, modelling, experiment*

1. Introduction

In the allied armies of NATO, AVTP (Allied Vehicle Testing Publications) are to be applied. The document regulates the mutual recognition of the results of tests and assessment of military vehicles in accordance with NATO standards. AVTP procedures are strictly defined for each of the measurements and tests. The document includes the guidelines regarding the protection of confidential information developed during the research. In Poland, the research on military vehicles is strictly defined by the defence standards, regulating the competences of research and calibration laboratories (PN - EN ISO / IEC 17025), requirements, research conduct, reporting and the quality of the research [8]. The main purpose of the research is to acquire all the data confirming the important features of the vehicle and its usefulness for operations conducted under specific conditions (e.g. military, geographical or meteorological). The results are usually presented in a quantitative manner (e.g. values of speed, deceleration, force etc.) with the addition of qualitative description (e.g. user-friendliness, opinion of the soldiers etc.), covering the phenomena which cannot be measured. Therefore, it is sometimes necessary to develop non-standard methods or procedures of research in order to acquire specific results with regard to the vehicle tested. The research should be based on research plan [8] approved by proper military authorities. This category of research problems includes, but is not limited to, dynamic loads acting on the construction of the vehicle and its crew on the battlefield.

The work discusses selected fragments of numerical and experimental research on the dynamic loads acting on selected military vehicles. This kind of vehicles (including tanks, armoured fighting vehicles and wheeled troop carriers) is the standard combat equipment of the land army. The usefulness of the military vehicles is generally assessed on the basis of the following features:

firepower, protective features and mobility. Dynamic development in the field of anti-armour weaponry forces the manufacturers of the military vehicles to design new kind of vehicles or improving the existing ones. This is done by introducing effective and modern solutions, which determine the probability of survival of the vehicle and its crew on the modern battlefield. Designing new solutions or improving the existing ones is preceded by model research performed with various conditions. During the simulations, the results of dynamic loads during the use of the vehicle are analysed, e.g. resulting from the roughness of the road, firing, IED explosion, the vehicle being hit by a shell etc. Model research [1, 2, 4, 5, 12] makes it possible to assess the expected dynamic loads acting on the load-bearing structure of a military vehicle, its underside and technological systems, as well as the limits of endurance of the crew in danger of serious injury and loss of life. The purpose of model and verifying research in the form of experiments [9, 11] is to improve the construction. In this case, it is a matter of improving the effectiveness and safety of operation of systems and installations of military vehicles, improving their mobility and introducing design solutions that ensure that the crew survives and the vehicle is more resistant against various forces. The construction tests under consideration assume extreme loads resulting from the phenomena that can be expected on a modern battlefield. It is worth emphasising that the safety of the crew and transported troops is one of the basic requirements in designing and improving military vehicles [13]. Main battle tank is the most refined solution that meets the conditions of the battlefield. Due to a unique selection of military vehicles discussed results of simulation, analyses and the experimental research are qualitative rather than quantitative.

2. Model and experimental research

Among the used models of military vehicles, discrete models are applied, described with the equilibrium equations in the adjusted Lagrange description, for which special numerical software was developed. A separate group consists of the models of higher complexity, developed on the basis of the finite element method. This group of models covers dynamic, quickly changing and highly non-linear problems with forces acting for a very short time. Complex numerical calculations are performed with the use of advanced computing systems, e.g. [7]. Experimental research serves the basic purpose of the assessment of the prototypical construction design in terms of the level of attainment of the assumed combat, construction and performance parameters. This type of research is the basis of the verification of the results of the model research. The examples below present a selection from a number of numerical models and the respective military vehicles subject to testing. The tests covered strength and safety requirements under the assumed conditions of use.

2.1. Light tank based on a multirole combat platform

Model research on a light tank based on “Anders” multirole combat platform was performed in two phases. In the first phase, discrete models of the tank were analysed in terms of assessing the dynamic loads acting on the tank and its crew when moving on selected types of road roughness and at the time the tank falls down from various heights. As an addition to the research, dynamic features and phenomena connected with the start of the vehicle were analysed in order to assess the dynamic features of the tank [10].

In the second phase, deformations and tension in the model of the tank were analysed (Fig. 1a), a result of the loads with a very short time of operation [1, 3, 12, 13]. The experimental research was conducted with a demonstrator of “Anders” tank (Fig. 1b) while firing the main armament, 120-gauge, for four directions of positioning the tank turret with regard to its longitudinal axis (0°, 90°, 180° and 360°) [9, 11], and with selected road tests [11]. Fig. 2 depicts the changes of the accelerations acting on the centre of mass of the tank over time.

a)

b)

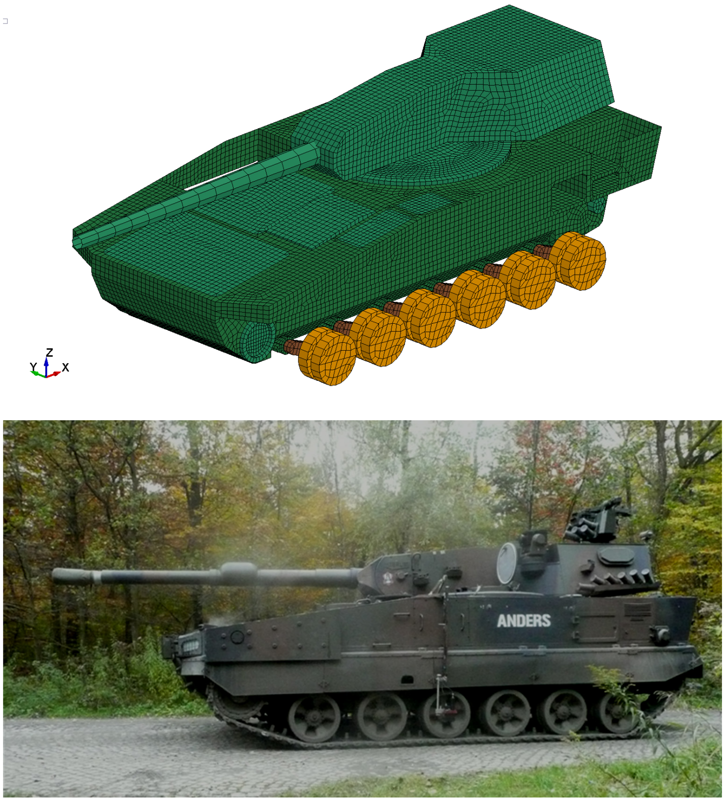


Fig. 1. Light tank: a) model, b) Anders technology demonstrator during a road test

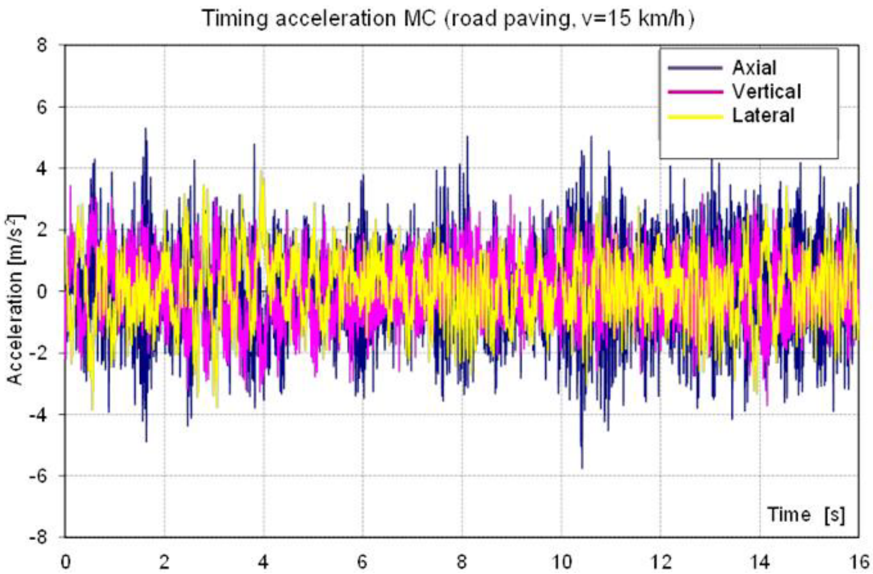
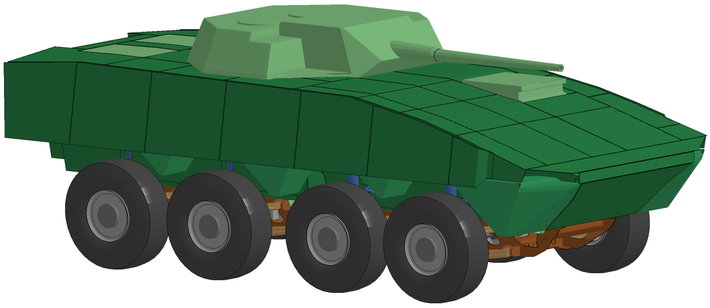


Fig. 2. Accelerations acting on the centre of mass of the tank over time during the travel with v = 15 km/h

2.2. Armoured Personnel Carrier (APC)

Research on APC cover similar scope of problems as those described in the case of the light tank, with one significant difference – the model structure was developed on the basis of already existing construction (Fig. 3b). The main research effort focused on determining the resistance of APC and the probability of survival of the crew and troops during the events typical for peacekeeping and stabilization missions [1, 4-6, 12]. Exemplary results of the model research are presented in Fig. 4, 5 and 6. Another features analysed were dynamic features under conditions of engine power reduced due to certain reasons.

a)



b)

Fig. 3. Armoured Personnel Carrier Rosomak: a) model; b) actual vehicle

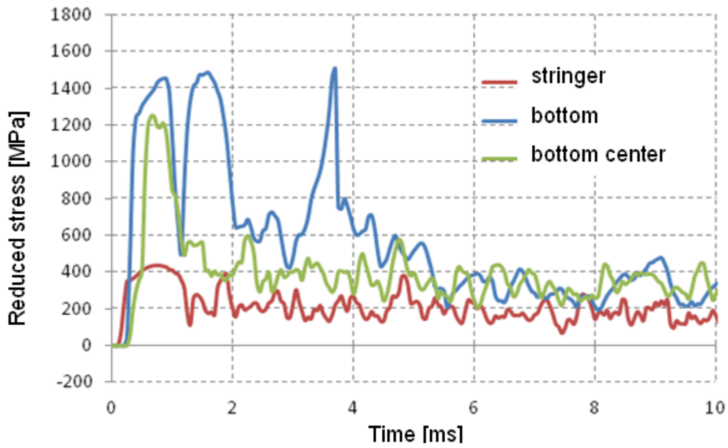


Fig. 4. Changes in tensions in selected structural nodes resulting from non-contact explosion

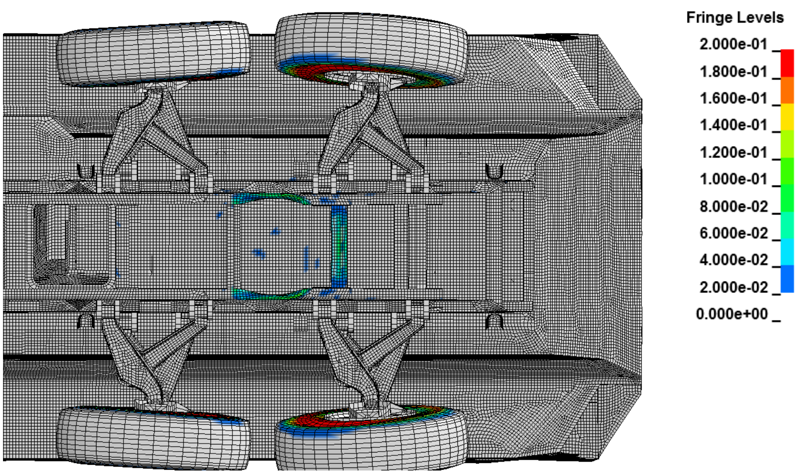


Fig. 5. Plastic strain of the element of the construction of the underbody resulting from non-contact explosion

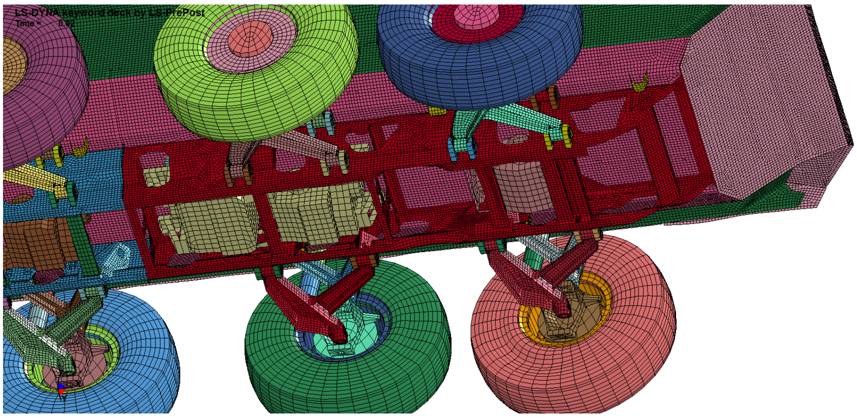


Fig. 6. Deformations of the element of the construction of the underbody (chassis and suspension) resulting from non-contact explosion

2.3. Direct Fire Support Vehicle

The purpose of the simulations performed for various conditions was to determine the required parameters included in the design of the future direct fire support vehicle. Several design solutions were analysed in terms of determining the parameters of suspension and its resilience characteristics for various combinations of construction solutions of the resilient elements. Numerical research was based on a hypothetical model of the vehicle, presented in Fig. 7a, whereas fig. Fb depicts the exemplary results of measurements of vertical accelerations acting on the vehicle and its crew while travelling through a single sinuous obstacle.

a)

b)

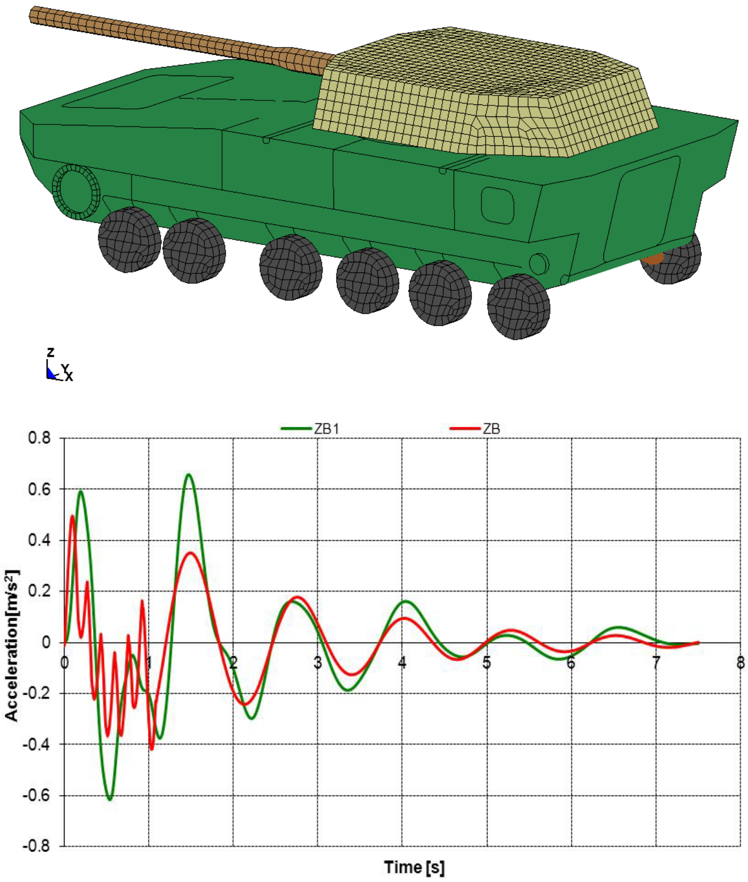
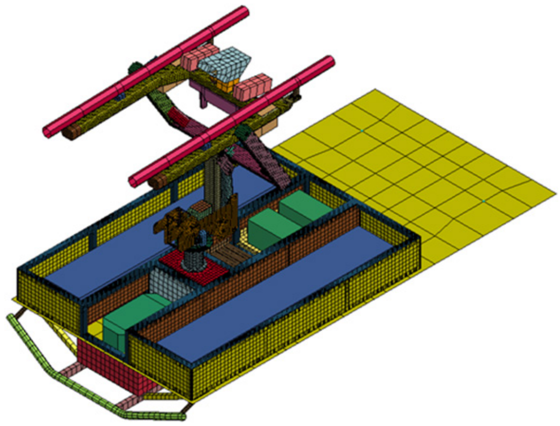


Fig. 7. Direct Fire Support Vehicle: a) model, b) vertical accelerations acting on the vehicle and its crew while travelling through a single obstacle

2.4. Anti-aircraft weapon system

Simulation and experimental research, covering various conditions, was conducted for the already existing, prototypical construction of "Kusza" anti-aircraft weapon, deployed on Polaris Ranger 6x6 underbody. The purpose of the research was to develop high resistance of the load-bearing structures of the weapon system in terms of the predicted type and conditions of usage. A model of anti-aircraft weapon system (Fig. 8a) was developed on the basis of a prototype solution (Fig. 8b). The main purpose of the model research was to assess the strain at the selected structural nodes and the level of dynamic loads acting on the weapon system and its crew. Exemplary research results are presented in Fig. 9, depicting the spatial operation of forces acting on the joint of load-bearing construction of the anti-aircraft launcher. To a limited degree, tests of the construction were conducted on the training ground, after introducing the modifications recommended as a result of simulating numerical research. The results indicate that the load-bearing structure is highly resistance, which allows for the use of the weapon set under virtually every conditions.

a)



b)

Fig. 8. „Kusza" anti-aircraft weapon system: a) model, b) anti-aircraft launcher on Polaris Ranger 6x6 underbody during training ground tests under winter conditions

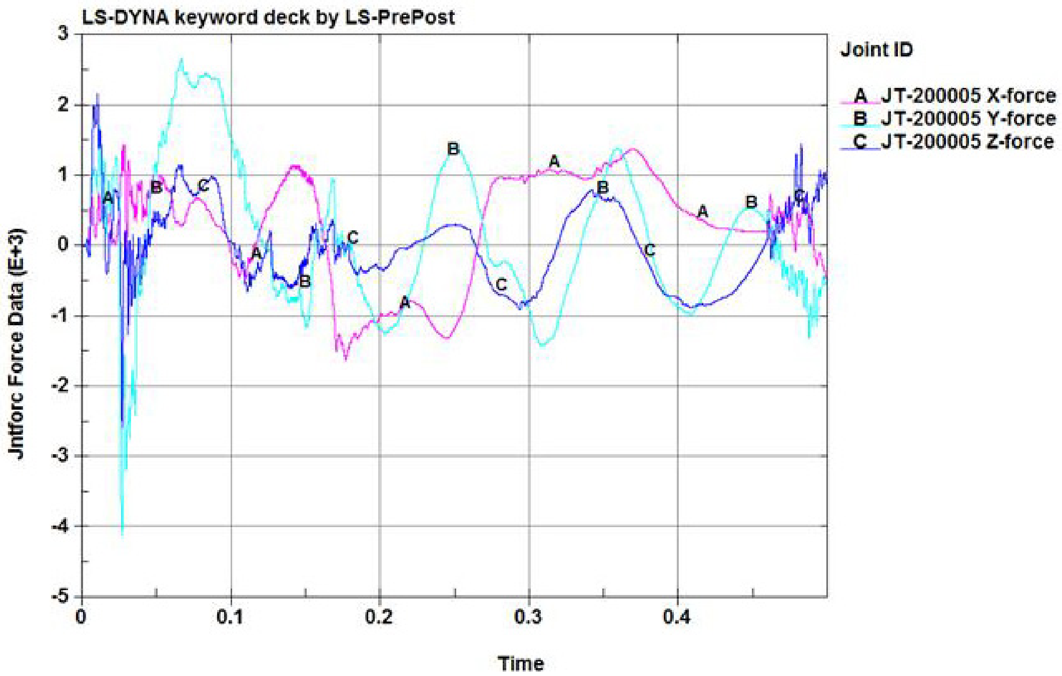


Fig. 9. Change of forces over time at the joint of the load-bearing structure of the anti-aircraft launcher

Conclusions

With description of selected military vehicles presented in the work, as well as scope of model and experimental research, the work presents the method of assessing the prototype or improved constructions in terms of meeting the assumed combat, construction and performance requirements. Some situations on the modern battlefield cannot be predicted but it is still possible to assume hypothetical conditions of using military vehicles (including the crew) in the simulation research and the strength of the construction and endurance of the crew to the dynamic loads.

Acknowledgement

Praca naukowa finansowana ze środków na naukę w latach 2007-2014 oraz z projektu DOBR – BIO4/017/13411/2013.

References

[1] Borkowski, W., Rybak, P., Hryciów, Z., *Badania struktur ochronnych wozów bojowych obciążonych wybuchem*, Journal of KONES, Vol. 14, Nr 1, 2007.
[2] Borkowski, W., Rybak, P., *Ochrona pasywna pojazdów specjalnych*, Journal of KONES, Vol. 14, Nr 4, 2007.
[3] Borkowski, W., Łęgowski, Z., Rafa, J., Rybak, P., *Modelowanie propagacji powybuchowych fal uderzeniowych w przestrzeni ograniczonej dwiema sztywnymi płaszczyznami*, Biuletyn WAT, Nr 11, 1998.
[4] Borkowski, W , Rybak, P., *Dynamic load in operation of high-speed tracked vehicles*, Journal of KONES, Vol. 16, Nr 4, 2009.
[5] Borkowski, W., Hryciów, Z., Rybak, P., Wysocki, J., *Badania skutków oddziaływania improwizowanych ładunków wybuchowych na KTO w wersji specjalnej*, Górnictwo Odkrywkowe, Nr 4/2010, Wrocław 2010.
[6] Borkowski, W., Hryciów, Z., Rybak, P., Wysocki, J., *Badanie skutków oddziaływania ładunków wybuchowych na konstrukcję transportera opancerzonego*, Systems Journal of Transdisciplinary Systems Science, Vol. 16, No 1, Wrocław 2012.
[7] *LS-DYNA Keyword User's Manual. Version 971/Release 4*, Livemore Software Technology Corporation, Livermore 2009.
[8] Zestaw Norm Obronnych NO-23 –A502. Technika wojskowa – Badania wojskowych pojazdów mechanicznych – Część 1, 2010, Część 2, 2011, Część 3, 2012, Część 4, 2012.
[9] Raczyński, Z., *Badania parametrów wytrzymałościowych kadłuba pojazdu gąsienicowego.* Biuletyn Naukowo-Techniczny Ośrodka Badawczo-Rozwojowego Urządzeń Mechanicznych – „OBRUM", Szybkobieżne Pojazdy Gąsienicowe (28), Nr 2, Gliwice 2011.
[10] Rybak, P., Borkowski, W., Wysocki, J., Hryciów, Z., Michałowski, B., *Badania modelowe lekkiego czołgu na bazie wielozadaniowej platformy bojowej*, Biuletyn Naukowo-Techniczny Ośrodka Badawczo-Rozwojowego Urządzeń Mechanicznych – „OBRUM", Szybkobieżne Pojazdy Gąsienicowe (28), Nr 2, Gliwice 2011.
[11] Rybak, P., Borkowski, W., Wysocki, J., Hryciów, Z., Michałowski, B., *Badania eksperymentalne lekkiego czołgu na bazie wielozadaniowej platformy bojowej*. Biuletyn Naukowo-Techniczny Ośrodka Badawczo-Rozwojowego Urządzeń Mechanicznych – „OBRUM". Szybkobieżne Pojazdy Gąsienicowe (28), Nr 2, Gliwice 2011.
[12] Rybak, P., *Kształtowanie odporności udarowej struktury nośnych wozów bojowych*, Wojskowa Akademia Techniczna, Warszawa 2013.
[13] Stanag 4569, *Poziomy zabezpieczenia osób znajdujących się w logistycznych i lekkich pojazdach opancerzonych*, (NATO STANAG 4569: *Protection Levels for Occupants of Logistic and Light Armoured Vehicles*), May 2004.