ISSN: 1231-4005
e-ISSN: 2354-0133
DOI: 10.5604/12314005.1136825

EXPERIMENTAL RESEARCHES OF DYNAMIC LOADS OF ARMOURED PERSONNEL CARRIER AND ITS CREW DURING COLLISION WITH RIGID OBSTACLE AND ALL-TERRAIN VEHICLE

Wacław Borkowski, Zdzisław Hryciów, Piotr Rybak, Józef Wysocki, Andrzej Wiśniewski

Military University of Technology
Institute of Motor Vehicles and Transportation
Kaliskiego Street 2, 00-908 Warszawa, Poland
tel.: +48 22 6837403, fax: +48 22 6837370
e-mail: zhryciow@wat.edu.pl

Abstract

The paper presents problems related to dynamic loads of armoured personnel carriers design as well as soldiers located inside them. During tactical operation, there is often the need for ramming other vehicles or terrain obstacles in order to provide road possibility. The lack in armoured vehicles, commonly used in cars crumple zones, will result in large values of accelerations. This can cause significant risk to the crews of vehicles.

In order to assess the exposure of soldiers while overcoming terrain and engineering obstacles experimental studies were performed covering a carrier's collision with a rigid barrier and ramming of all-terrain vehicle. In the paper the research conditions and used measurement equipment were described. A four-wheel SKOT personnel carrier and Tarpan Honker car, out of service, was used for the tests. The tests were carried out within the area of the Military Institute for Armoured and Automotive Technology in Sulejówek. During crash tests, anthropomorphic measurement equipment – Hybrid III 50th Male Dummy type – was used for recording the values of loads affecting the soldiers. The article presents some results of experimental studies. The values of the carrier's body accelerations in driver's and landing troop compartment were compared as well as dynamic loads of test dummies. The results obtained during vehicle ramming prove that these types of actions do not cause serious threats for the members of the carrier crew.

Keywords: *armoured personnel carrier, dynamic load, dummy, crash test, passive safety*

1. Introduction

During military operations, armoured vehicles and mostly soldiers located inside them are exposed to the influence of various threats. Basic ones obviously include the action of combat means – missiles and explosives. They usually result in serious vehicle damage. Other group of threats include the ones that result from vehicle motion and their collisions with other vehicle or obstacles. In many situations they are not accidental but result from a need for ramming – e.g. in order to provide road possibility.

During the initial analysis it was stated that [1, 3], a serious limitation for ramming ability is not caused by the very structure of the vehicle but a threat to the crew, resulting from a high level of a load of inertia when hitting an obstacle. Unlike passenger cars, where the crumple zone absorbs a significant portion of the impact energy and in the military vehicles where the structure rests on a rigid frame or on a self-supporting body, there is a lack of technical solutions that can soften the impact effects.

The basic purpose of this paper was to define a level of dynamic loads affecting an armoured personnel carrier and its crew during a frontal collision with a rigid barrier and a passenger all-terrain vehicle at low impact velocities. Obtained test results also made a basis for verification of numerical models.

2. Research object and methodology

Due to a lack of access to Rosomak armoured personnel carrier, which could be destroyed during the crash tests, a four-wheel SKOT personnel carrier, command centre version, out of service, was used for the tests. The tests were carried out within the area of the Military Institute for Armoured and Automotive Technology in Sulejówek, using their vehicles and test dummies.

Figure 1 presents a view of a track finished with a rigid retaining wall and a personnel carrier prepared for a crash test.

Fig. 1. The view of a test track with a rigid retaining wall and a personnel carrier prepared for a crash test

During crash tests, anthropomorphic measurement equipment – Hybrid III 50th Male Dummy [5] type – was used for recording the values of loads affecting the soldiers. 50-centile male test dummy Hybrid III is the most common dummy used in the automotive industry. It is used to evaluate the safety and structure. It allows acquisition of physical values truly reflecting a possible influence on a human body. That kind of equipment is basically designed for frontal car crash tests. A dummy located in the driver compartment was placed on a standard seat of the SKOT vehicle, without a headrest, and fastened with four-point seat belts. A dummy located in the landing troop compartment was placed on a seat making standard equipment for an APC Rosomak and it was fastened with a lap belt (Fig. 2).

Fig. 2. A dummy located in the driver compartment (left) and in the landing troop compartment (right)

The tests were performed by accelerating the carrier by means of a truck. The carrier's driving system was disconnected for the testing time. The scope of the tests included a collision of the armoured personnel carrier and a rigid concrete wall for two velocities: 6 and 12 km/h. During the tests, the velocity was initially defined by GPS equipment while the real velocity before the crash was defined on the basis of the records made by a fast video camera each time. Three trials were carried out for each velocity. The tests included an additional element – crash tests of an armoured carrier with an immobile all-terrain vehicle, Tarpan Honker, placed longitudinally and crosswise (right and left sides) towards the carrier motion. These tests were performed for a velocity of about 30 km/h.

Two fast video cameras were used for recording the impact process. Additionally, in order to record displacement of the dummies located inside a vehicle, two GoPro HERO video cameras were used. Apart from the measurement apparatus related to the Hybrid III dummies, two independent measurement circuit were installed in the carrier used for measuring the acceleration of the body during the tests. The first of them included the ACCINO system, making the integrated measurement and recording system with own supply system [4]. The second system included the ACA Digital X10D measurement computer, the DaqBook measurement card, the conditioner module and two triple-axis piezoelectric accelerometers, Brüel&Kjær 4504 type.

3. Test results

Courses of analysed values, recorded during experimental tests, were subject to filtration and scaling. In relation to the body acceleration, a digital filter in accordance with CFC60 was used. Its limit frequency amounts to 100 Hz. Fig. 3 presents examples of longitudinal acceleration courses for two impact velocities: 5.94 and 11.52 km/h. In all cases, courses of the body decelerations are very similar. Differences only refer to obtained extreme values. Deceleration duration amounted to about 80 ms. At this time the carrier was stopped and then was rebounded from the retaining wall.

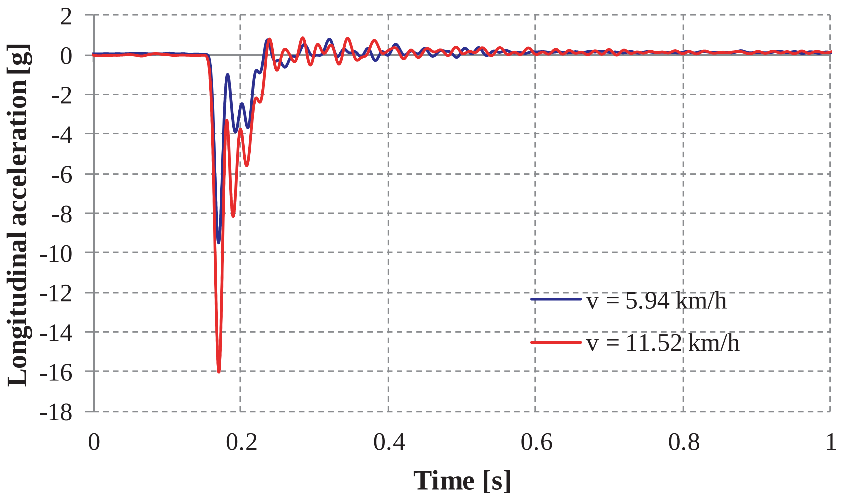

Fig. 3. Comparison of the longitudinal acceleration for the trial 3 and 4

Table 1 specifies, defined on the basis of analysis of the records from the fast video cameras, real impact velocities and recorded maximum body deceleration values in the landing troop compartment for individual trials. Obtained results are illustrated in Fig. 4.

Higher homogeneity of obtained results can be observed for lower impact velocities (trials 1-3), however a close relation between velocity and deceleration has not been obtained. It was mostly caused by the fact that the carrier did not always move perpendicularly towards the frontal surface of the barrier at the final stage of motion.

Much higher dispersion in obtained results was observed for trials 4-6. Increased velocity negatively affects a possibility of directing the carrier on the obstacle. Moreover, in case of higher impact velocities, there was a minor damage to the upper edge of the retaining wall and the front section of the carrier was increasingly tossing up. And also, the front armour plate was broken.

Tab. 1. Maximum body deceleration

Trial	Velocity [km/h]	Body deceleration [g]
1	5.58	5.24
2	6.48	7.98
3	5.94	9.49
4	11.52	16.02
5	12.53	13.43
6	12.06	10.07

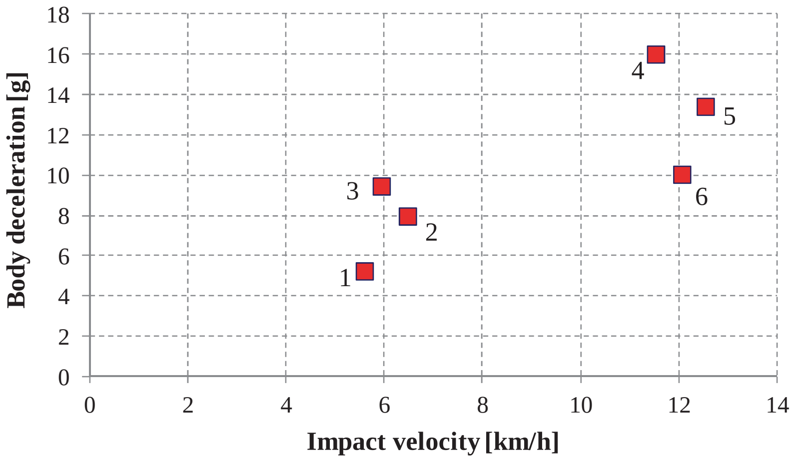

Fig. 4. The distribution of maximum body deceleration

Figure 5 specifies chosen phases of collision with a concrete obstacle for a trial no. 4. The impact took place at 150 ms of the measurement time (according to the courses in Fig 3 and 8).

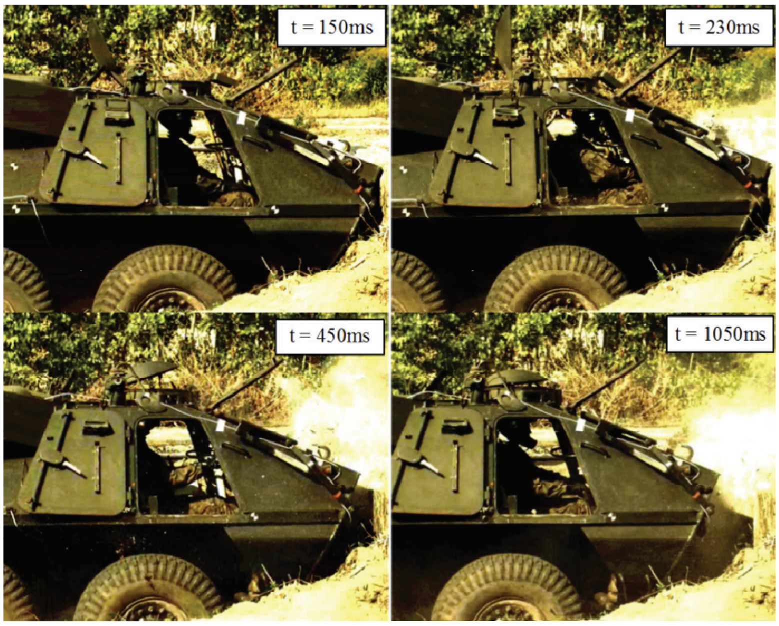

Fig. 5. Phases of APC collision with a concrete obstacle (trial no. 4)

Due to a rigid structure of the body, no significant body deformations were recorded. Only the carrier motion stopping is visible on it and then its recoil from the wall as well as the dummy motion in the driver's compartment. The carrier stopped after about 900 ms from the moment of impact.

Figure 6 presents three phases of motion of the dummy located in the driver's compartment. After 120 ms from the impact, the maximum bending of the dummy's neck occurs. In case of higher velocities, the dummy's head also hits the edge of a hatch in the ceiling plate. It generates high values of forces squeezing the neck. Due to the use of a four-point seat belt, motion of the whole body is significantly limited. Only motion of the head and shoulders is visible. After 300 ms, the body bends backwards, which is characteristic for frontal collisions. The body is stopped on the backrest of the seat, while the head, in case of no head restrain, strongly tilts backwards.

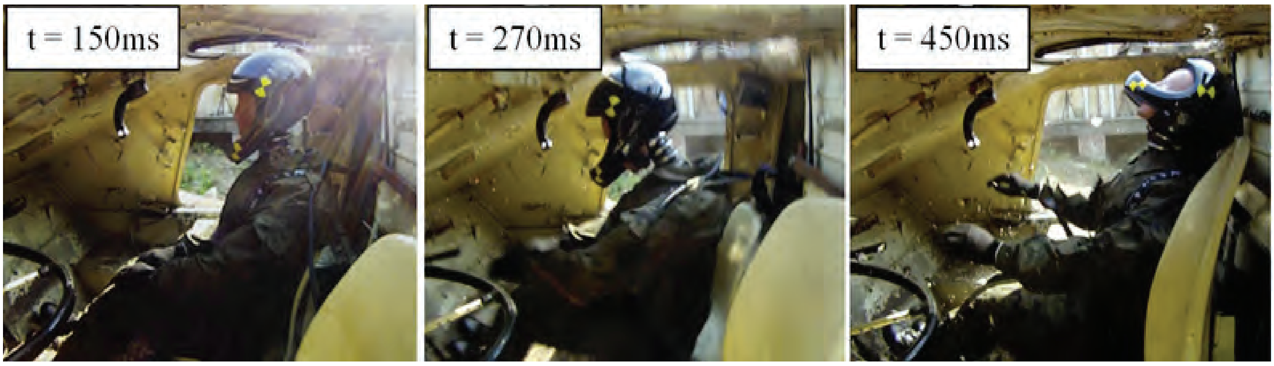

Fig. 6. Phases of motion of the dummy located in the driver's compartment (trial no. 4)

Different behaviour can be observed for a dummy located in the landing troop compartment (Fig. 7). The dummy is placed on a seat located crosswise towards direction of motion and it is protected with just a lap belt. In about 300 ms from the moment of impact, the maximum dummy displacement can be observed. Due to the fact that the pelvis is held by the belt, the body and the heads bend to the right side with simultaneous bending forward and a slight turn against the vertical axis. After the impact, the dummy does not fully return to its initial position and stops after about 660 ms.

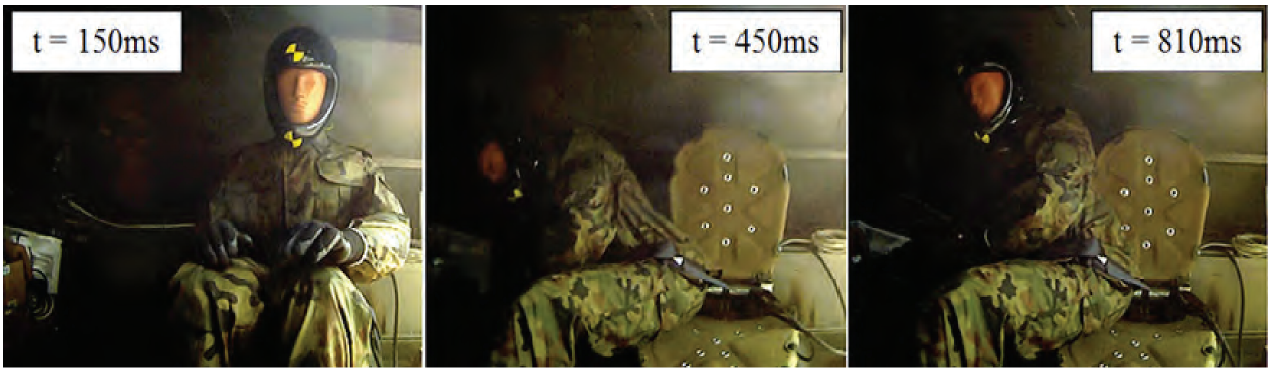

Fig. 7. Phases of motion of the dummy located in the landing troop compartment (trial no. 4)

Figure 9 presents an example of the course of the neck bending moment for a dummy located in the driver's compartment for a trial no. 4. It shows indicated points where extreme values were obtained during head bending.

At the beginning, there is a short moment of bending the head backwards when the dummy's torso is pushed upwards. After that stage, the dummy's head is bent forwards and the maximum value of the moment is reached. It makes a basis for further evaluation.

The maximum moments for individual trials are specified on fig. 9. It should be mentioned that in case of the dummy placed in the landing troop compartment, presented values refer to the moment of bending the head to the side (acting against the longitudinal axis of the dummy). The maximum values were obtained for a trial 5 and amounted to about 31 Nm. Once again, higher harmony in obtained results was stated for lower velocities.

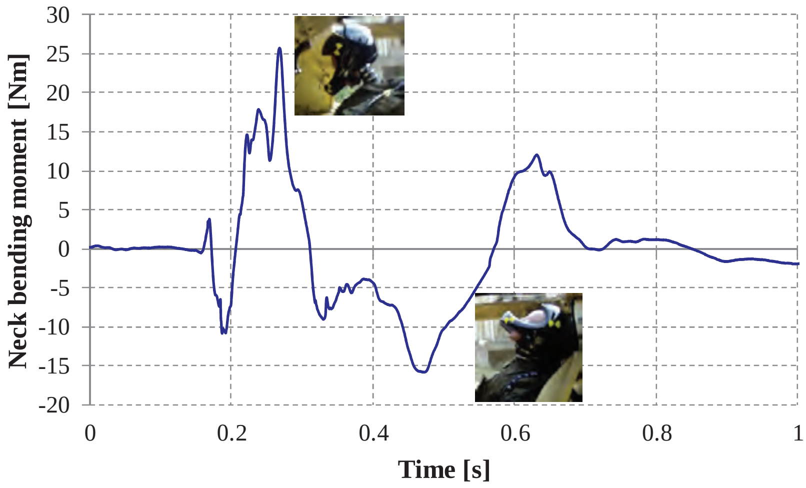

Fig. 8. The course of the neck bending moment for a dummy located in the driver's compartment (trial no. 4)

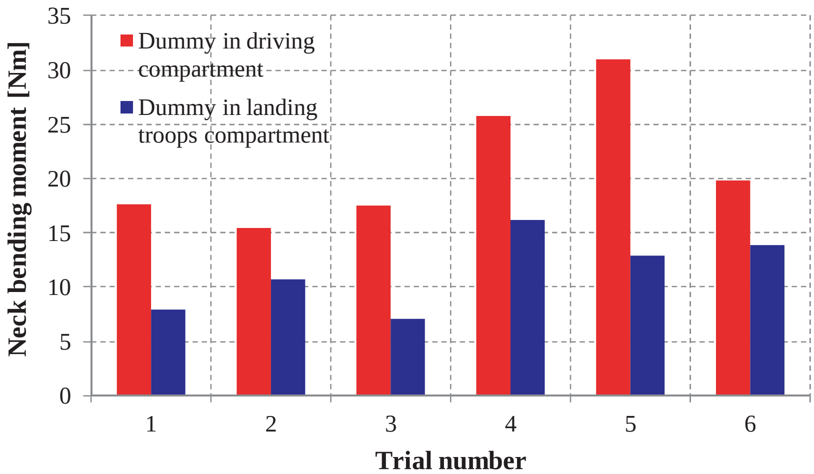

Fig. 9. The maximum values of neck bending moment

Table 2 specifies the maximum values of moments and forces in the neck and head deceleration for considered dummies as well as the limit values for frontal crash tests [2]. For the dummy located in the landing troop compartment, the value of the crosswise head deceleration was given. Due to a different dummy location against the vehicle, a direct comparison of individual measured values is not possible.

Tab. 2. Summary of results for test dummies

Trial	A driving compartment			A landing troop compartment		
	M_Y [Nm]	F_Z [N]	a_X [g]	M_X [Nm]	F_Z [N]	a_Y [g]
1	17.66	418.39	5.97	7.95	92.51	2.31
2	15.42	483.22	5.68	10.75	104.39	3.83
3	17.52	513.18	5.98	7.09	77.60	2.31
4	25.73	708.21	28.67	16.18	223.46	6.00
5	30.96	722.08	23.02	12.94	279.02	3.77
6	19.84	742.87	14.40	13.89	329.48	5.28
The limit values	57	1100	88	—	1100	—

When comparing obtained results, it can be stated that the dummy located in the driver's compartment is subject to higher loads. Due to the fact that it is fastened with a four-point seat belt, its ability to move is limited and as a result, it increases the loads occurring in the head and in the neck.

The limit values were not exceeded in any analysed case. The highest values, recorded during the tests, for the neck bending moment and the tension force for a fifth trial are about 1/3 times lower than the limit values. Momentary head acceleration values for a trial 4 are three times lower than the acceptable values for a 3 ms duration.

At the second stage of the research, three crash tests with a motionless vehicle, Tarpan Honker, placed longitudinally and crosswise against direction of the carrier motion, were carried out. Fig. 10 presents selected phases of the crash for a vehicle placed crosswise to the right side.

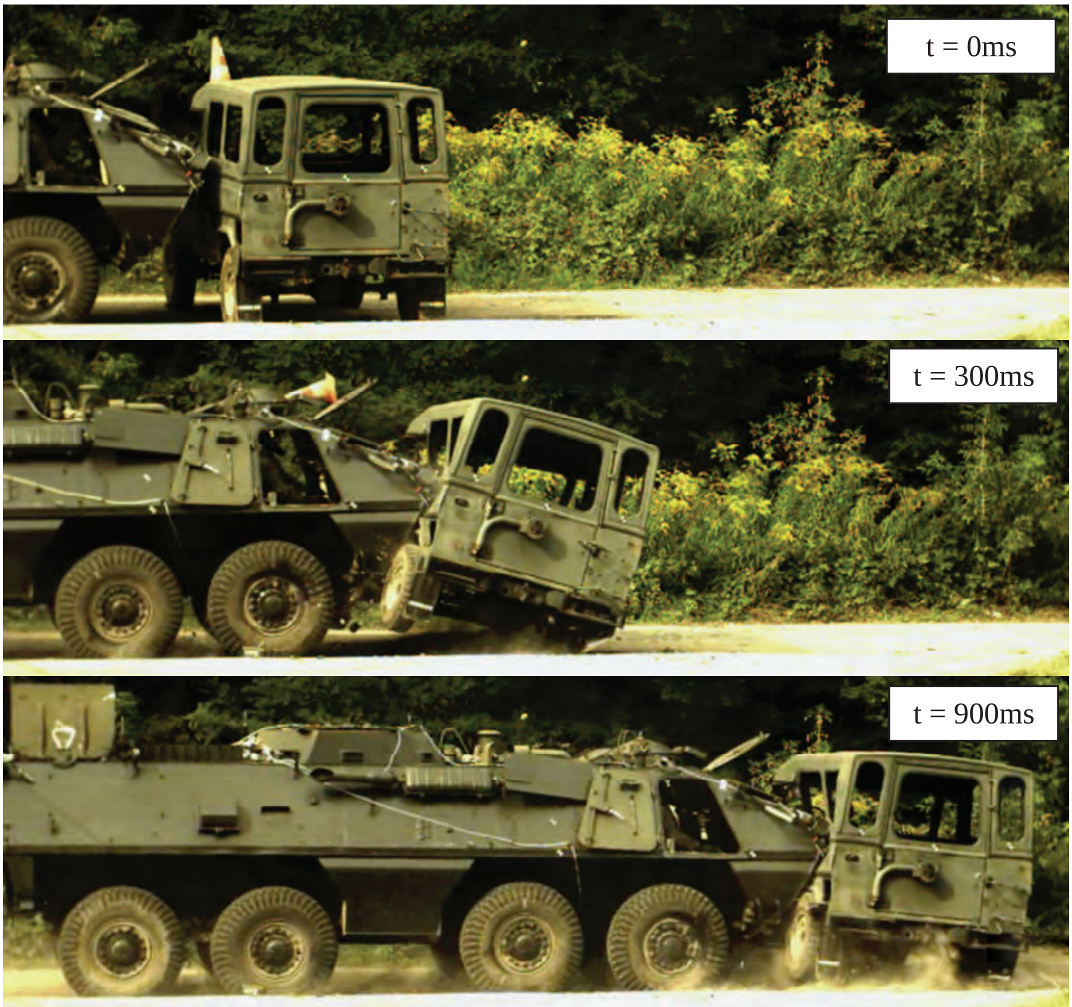

Fig. 10. Phases of APC collision with a Tarpan Honker

After collision, the vehicle was pushed sideways until complete stopping. While in case of the crash test when hitting a vehicle in the back, it was pushed forward. Due to big differences in weights of the vehicles taking part in the collision (11 960 kg for the SKOT personnel carrier and 1360 kg for the Tarpan Honker), recorded values for the carrier body decelerations are many times lower than the values obtained in the crash tests with a rigid wall. The maximum decelerations values amounted to about 1 g.

3. Summary

The results presented in this paper make a part of the experimental and simulation research carried out in order to define a level of threat for the armoured carrier crew during collision with various objects. The crash tests with a rigid concrete obstacle were performed at lows velocities that did not result in serious vehicle damage.

Higher values of deceleration and the neck forces and moments were observed for the dummy located in the driver's compartment. It mostly resulted from a different fastening method. Higher dummy displacement in the landing troop compartment reduced the values of forces and accelerations. However, it should be underlined that only a single seat was used in the tests. In the real conditions, several soldiers sit next to each other in the landing troop compartment. In such situation, there is a possibility that a soldier's head or body can hit the elements of neighbouring seat, equipment or a soldier sitting on the next seat during collision.

The results obtained during vehicle ramming prove that these types of actions do not cause serious threats for the members of the carrier crew. It results from high differences in the vehicle weights. However, it should be kept in mind that in case of ramming the smaller cars they can get stuck under the carrier's wheels.

Acknowledgements

The scientific work financed by the funds assigned for the science in years 2010-2013 as a research project.

References

[1] Borkowski, W., Hryciów, Z., *Preliminary Investigation of Dynamic Loads of the Crew of the Armored Personnel Carrier During Frontal Crash*, Journal of KONES Powertrain and Transport, Vol. 15, No. 4, pp. 57-62, 2008.

[2] *European New Car Assessment Programme (Euro NCAP). Assessment Protocol – Adult Occupant Protection, Version 5.2*, June 2010.

[3] Orłowski, L., Pędzisz, M., Rzymkowski, C., *Wyniki wstępnych badań eksperymentalnych oraz komputerowej symulacji zagrożenia osób w trakcie uderzenia w przeszkodę wojskowego samochodu terenowego*, Journal of KONES Powertrain and Transport, Vol. 14, No. 3, pp. 495-502, 2007.

[4] Pawłowski, P., Cetnarowicz, D., *ACCINO. Instrukcja użytkownika. Wersja 3.3.*, Politechnika Poznańska, Katedra Sterowania i Inżynierii Systemów, Pracownia Układów Elektronicznych i Przetwarzania Sygnałów, 2011.

[5] *Sign Convention for Load Cells*, (S.A.E. J-211), Robert A. Denton Inc., 2002.