EXPERIMENTAL RESEARCH ON THE DYNAMIC LOADS OF THE WHEELED ARMOURED PERSONNEL CARRIER

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Abstract

The results of the experimental research on the influence of the special vehicle movement conditions on the body shell and the vehicle crew dynamic load will be presented in the paper. ROSOMAK Wheeled Armoured Personnel Carrier (Wheeled APC), the basic version, was the subject of the research. The research work was aimed at analysis of the dynamic loads resulting from the deterministic inputs and driving on the selected types of surfaces generating random kinematic inputs. The personnel carrier service conditions, measuring apparatus, and testing methods will be described. The vertical accelerations of the selected points of the vehicle, and deflection of the prime and second suspension of the vehicle left side were measured. The time and the acceleration RMS value spectrum charts for the selected implementations will be presented. The cumulative statistics will be shown in the form of a table. The conclusions regarding the influence of the road surface on the personnel carrier driver's working comfort will be formulated. The assessment of the suspension quality will be included in the conclusions. Driving on the smooth surface is comfortable. However, the road surface worsening causes decreased proficiency sense until the exposure limit boundary is reached when the vehicle drives on a poor quality cobble road with 50 km/h speed. The vehicle basic version is not fitted with the seats for assault troops, therefore the influence of the road irregularities on the centre of mass of the body shell, and the driver's and commander's seats were determined. It is recommended to make further tests on the personnel carrier combat and special versions.

Keywords: *experimental research, dynamic loads, wheeled armoured personnel carrier, acceleration, vibrations*

1. Introduction

Independently of the gun turret, armament type, and armour, the basic task of the personnel carrier is to enable the crew to reach an assigned region efficiently and carry out the orders. Driving comfort significantly influence the mental and physical soldiers' state during military missions. Besides degree of protection, driving comfort is a significant criterion of assessment of the given means of transport. During operational use of ROSOMAK Wheeled APC under various terrain conditions many dynamic loads affect the vehicle. There are the following impact sources:

- engine (rotational speed and torque fluctuations);
- drive system (gear change, accelerating and braking, cornering);
- road surface (irregularities, slope, road adhesion);
- clearing terrain obstacles;
- armament operating (combat version);
- missile impact, mine and charge explosions.

The tested vehicle does not take part in combat activities, although it is exposed to the last two impact sources mentioned above during missions in unstable regions. Vibrations of the armoured body shell, caused by kinematic interactions associated with driving on unsurfaced roads, wilderness, natural and artificial obstacles, significantly influence the systems, circuits, and units of the combat vehicle in movement, during the operation life of the personnel carrier. The exposure levels mainly depend on the driving speed, the suspension dynamic properties, and interaction between the driving system and the road surface.

Fig. 1. Wheeled Armoured Personnel Carrier in basic version

2. Testing Methods and Measuring Apparatus

ROSOMAK 8 x 8 Wheeled APC, the basic version, was the subject of research (Fig. 1). The tests included the Wheeled APC dynamic loads analysis for various driving speeds on the roads with various surfaces, and for driving on the single irregularities. The experimental research on random inputs was made at the Military University of Technology (MUT) testing ground and at the selected roads with the following surfaces:

- the good quality asphalt road (the MUT internal road);
- the cobble road (the MUT internal road);
- the gravel road (the MUT testing ground);
- and the terrain road (unsurfaced) at the MUT testing ground.

The measurements for the individual lanes were taken for a single driving direction, with a constant speed (Fig. 2). During the measurement passages the driver was keeping the set speed, was not shifting the gear and was not changing the tire pressure. In order to verify the result repeatability three measurements were taken for each movement condition. Additionally, in order to get data especially useful for the numerical models verification, the measurements for the determined inputs were made. The measurements were taken at the irregularity with a triangle prism profile of height h = 0.17 m, length L = 4 m, and for the cosine irregularity of height h = 0.066 m and length L = 1.5 m, located on the asphalt surface. The measurements were taken for the following speeds:

- at the asphalt road: v = 10, 20, 30, 40, 50 km/h;
- at the cobble road: v = 10, 20, 30, 40, 50 km/h;
- at the testing ground road (wilderness): v = 10, 20, 30, 40 km/h;

The measurement speeds were selected on account of the safety and limits resulting from available run-up and stop lanes for the measurements for the higher speeds.

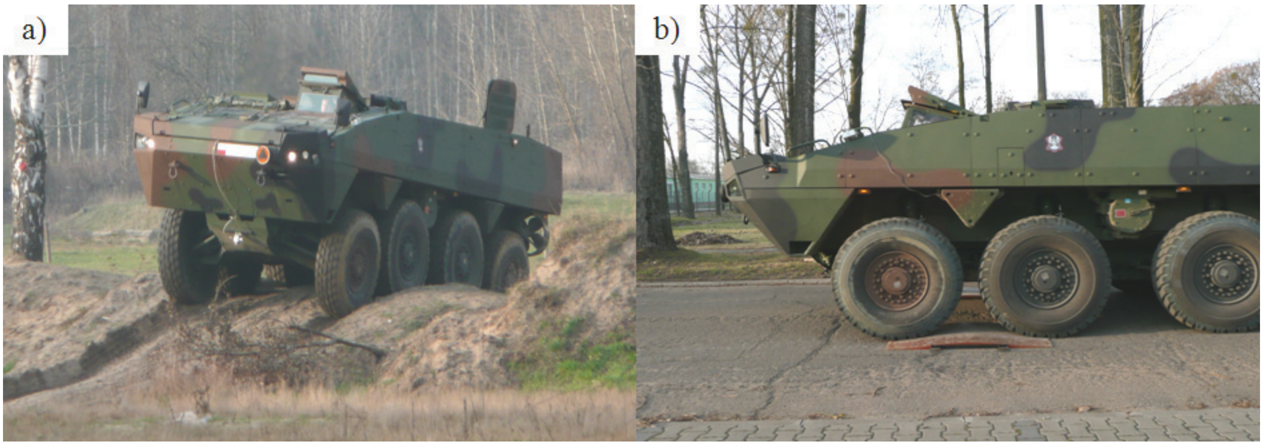

Fig. 2. Armoured vehicle during experiment:: a) at the testing ground road (wilderness), b) at the cosine irregularity

During the measurements the following parameters were measured:

- accelerations of the centre of mass for the three directions;
- vertical accelerations for the driver's seat;
- vertical accelerations for the commander's seat;
- vertical accelerations on the floor under the driver's seat;
- vertical accelerations of the vehicle front and back on the roll axis;
- vertical accelerations of the vehicle left and right sides on the lateral axis;
- vertical accelerations on the prime wishbone;
- dynamic deflection for the prime and second suspension of the vehicle left side.

The vertical direction concerns the accelerometers position when the vehicle is not in motion, and the direction perpendicular to the vehicle roll axis when the vehicle moves.

During the measurements three various measurement systems were used: Halikan logger, Pulse multianalyser and DAQBook measurement set. The personnel carrier crew and the Wheeled APC dynamic loads measurements were taken with the use of the following transducers:

- linear acceleration three-axis transducers with Delta Tron piezoelectric sensors and inductive sensors;
- acceleration single-axis transducers with the sensors as mentioned above, ADXL micromechanical sensors, and piezoelectric and inductive sensors;
- linear displacement inductive transducers (Fig. 3a);
- the vehicle speed optical transducer (Fig. 3b).

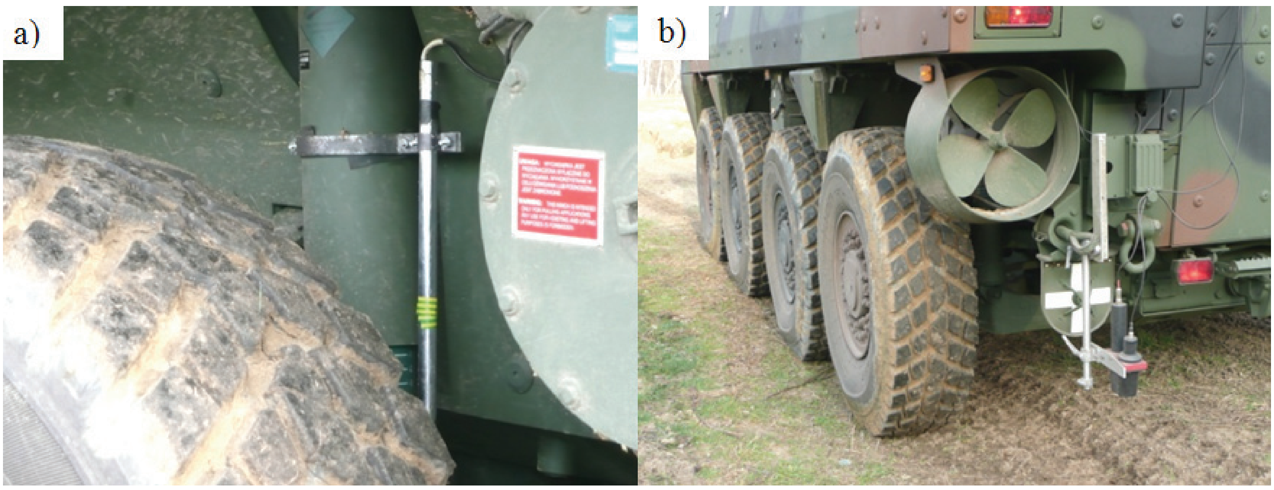

Fig. 3. Location of sensors outside vehicle:a) linear displacement inductive sensor; b) the vehicle speed optical sensor

The linear displacement sensors were mounted on the prime and second suspension on the left side, and the optical sensor was mounted at the vehicle back (Fig. 3). The appropriate amplifiers and the recording equipment were located inside the vehicle. The acceleration transducers were located inside the vehicle at the following places (Fig. 4):

1) at the driver/mechanic's seat (1) and the commander's seat (2);
2) at the personnel carrier centre of mass (three-axis) (3);

at the assault troops' compartment (4, 5, 6).

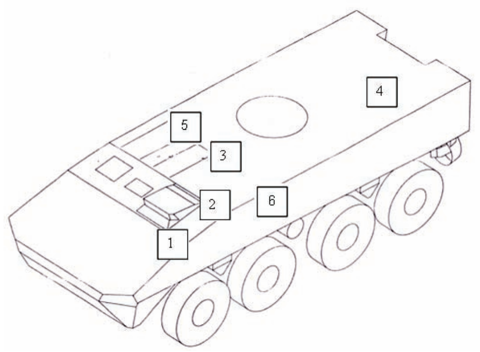

Fig. 4. Location of acceleration transcuders

3. The Experimental Research Results

The selected time charts for the tested surfaces, driving speeds and inputs are presented in the paper. Additionally, the setting-up for all variants is shown in the form of a table. The time charts for the vertical accelerations of the centre of mass and the driver, for the asphalt road, with the speed of 50 km/h, are shown in Figure 5. Maximum acceleration recorded for the vehicle body shell is 1.99 m/s^2, at standard deviation 0.46 m/s^2. Much higher accelerations affect the driver. The following accelerations were recorded: maximum 5.55 m/s^2, minimum –6.14 m/s^2, at standard deviation 1.22 m/s^2. The measured values are more than 2.5 times higher, although the accelerations measured on the floor under the driver's seat do not significantly differ from the accelerations of the centre of mass (the influence of the longitudinal angular vibrations at a small distance). Such behaviour of the driver's seat may result from the seat suspension system play, however it is necessary to examine the case by means of measurements of the vehicle representative sample. The basic statistics for the random inputs are presented in Tables 1, 2.

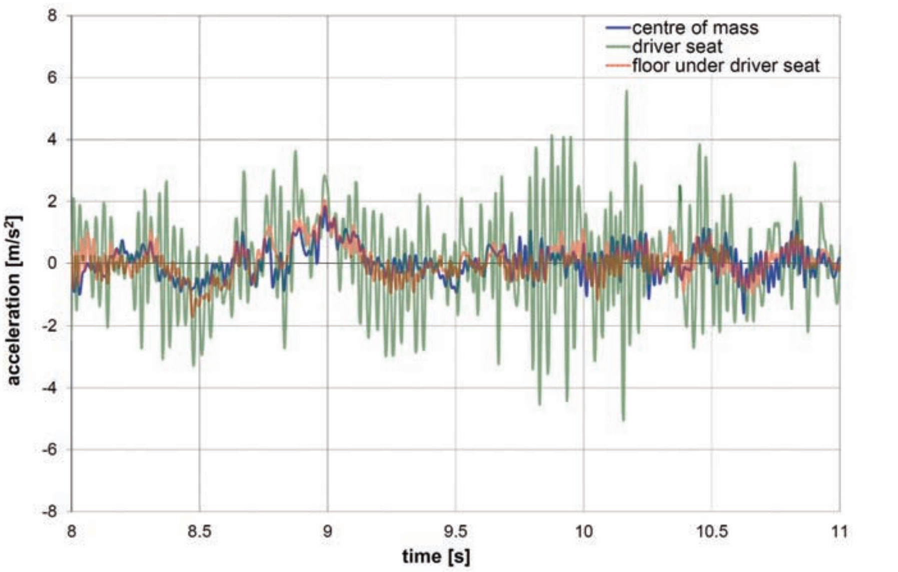

Fig. 5. Time chart of acceleration for centre of mass, driver seat and floor under driver seat during experiment on asphalt surface with 50 km/h vehicle speed

Tab. 1. Statistical summary of acceleration values for asphalt and cobble surface

		centre of mass			driver seat			floor under driver seat		
Surface	v [km/h]	a_{MAX} [m/s^2]	a_{MIN} [m/s^2]	std. dev. [m/s^2]	a_{MAX} [m/s^2]	a_{MIN} [m/s^2]	std. dev. [m/s^2]	a_{MAX} [m/s^2]	a_{MIN} [m/s^2]	std. dev. [m/s^2]
Asphalt	10	0.48	-0.48	0.14	1.76	-1.55	0.14	0.45	-0.42	0.38
	20	1.23	-1.07	0.3	3.43	-2.66	0.77	1.2	-1.09	0.31
	30	1.31	-1.23	0.33	3.52	-3.37	0.9	1.44	-1.17	0.33
	40	1.34	-1.32	0.4	4.96	-4.55	1.14	1.45	-1.46	0.42
	50	1.99	-1.59	0.46	5.55	-6.14	1.22	2.04	-1.9	0.48
Cobble	10	1.14	-0.94	0.31	1.68	-2.11	0.54	1.11	-1.04	0.32
	20	2.1	-2.64	0.56	6.47	-8.22	1.73	2.77	-2.37	0.63
	30	4.19	-2.65	0.74	9.49	-9.4	2.39	3.51	-3.48	0.91
	40	4.49	-4.64	1.19	12.89	-12.84	3.32	4.85	-4.14	1.31
	50	5.41	-5.9	1.24	16.89	-19.11	3.38	5.32	-4.97	1.34

Tab. 2. Statistical summary of acceleration values for gravel and unsurfaced road

		centre of mass			driver seat		
Surface	v [km/h]	a_{MAX} [m/s^2]	a_{MIN} [m/s^2]	std. dev. [m/s^2]	a_{MAX} [m/s^2]	a_{MIN} [m/s^2]	std. dev. [m/s^2]
Gravel	10	1.38	-1.41	0.40	1.59	-1.45	0.41
	20	1.10	-0.92	0.32	1.35	-1.29	0.41
	30	1.89	-1.82	0.49	2.20	-3.25	0.69
	40	2.16	-2.25	0.68	3.50	-5.41	1.11
Unsurfaced road	10	2.33	-9.26	0.66	2.74	-9.63	0.71
	15	4.29	-4.03	0.96	4.51	-4.95	1.05
	20	4.60	-4.52	1.12	7.32	-7.60	1.48
	25	3.54	-3.55	1.00	4.92	-4.57	1.51
	30	2.94	-3.45	1.03	4.78	-4.68	1.65

The spectral analysis of the time charts for accelerations and displacements was made. The fast Fourier transform algorithm implemented in MATLAB environment was used and RMS values of accelerations for 1/3 octave bands with the use of the power density spectrum numerical integration were determined. The acceleration RMS value spectrum charts were made for 1/3 octave middle bands up to the frequency of 20 Hz. Example charts for the asphalt surface at various driving speeds are presented in Fig. 6. For the asphalt surface, at a low driving speed (10 km/h) the comfort boundary was not exceeded. The comfort boundary was exceeded when the driving speed increased up to 50 km/h, but the fatigue-decreased proficiency boundary was not exceeded.

The analogous charts for accelerations for the cobble surface are presented in Figure 7. As for the asphalt surface, the implementations for the vehicle speeds of 10 and 50 km/h are presented. It may be observed that the comfort boundary was exceeded for the frequencies of 2 and 4 Hz. For the speed of 50 km/h the comfort and fatigue-decreased proficiency boundary were exceeded, and for the frequency of 10 Hz the exposure limit boundary was exceeded.

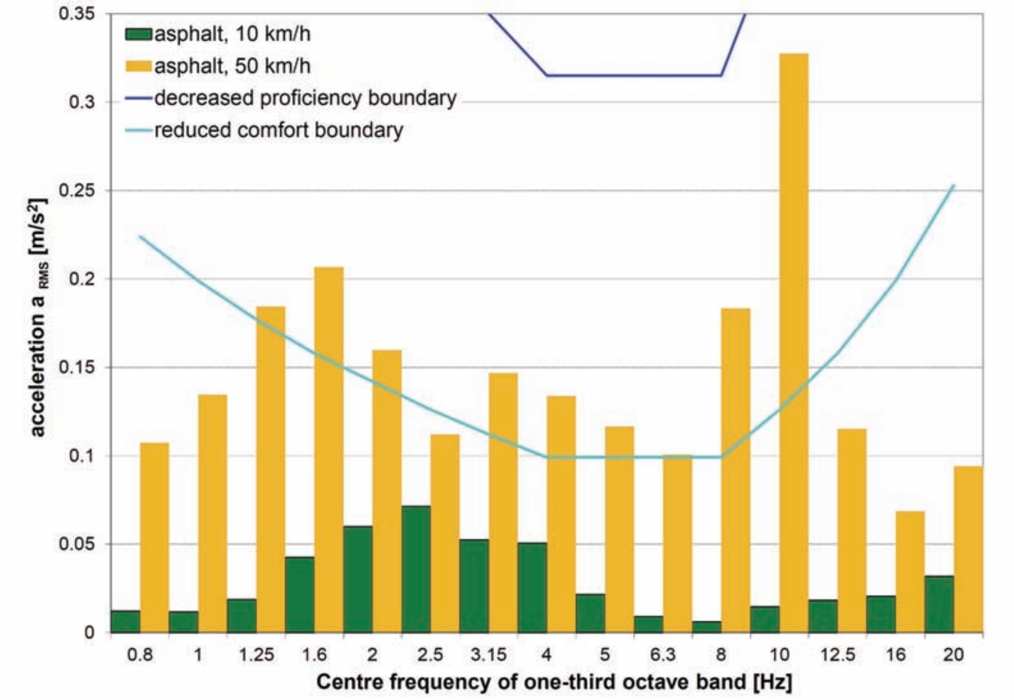

Fig. 6. The acceleration RMS value spectrum chart for driver seat on asphalt surface

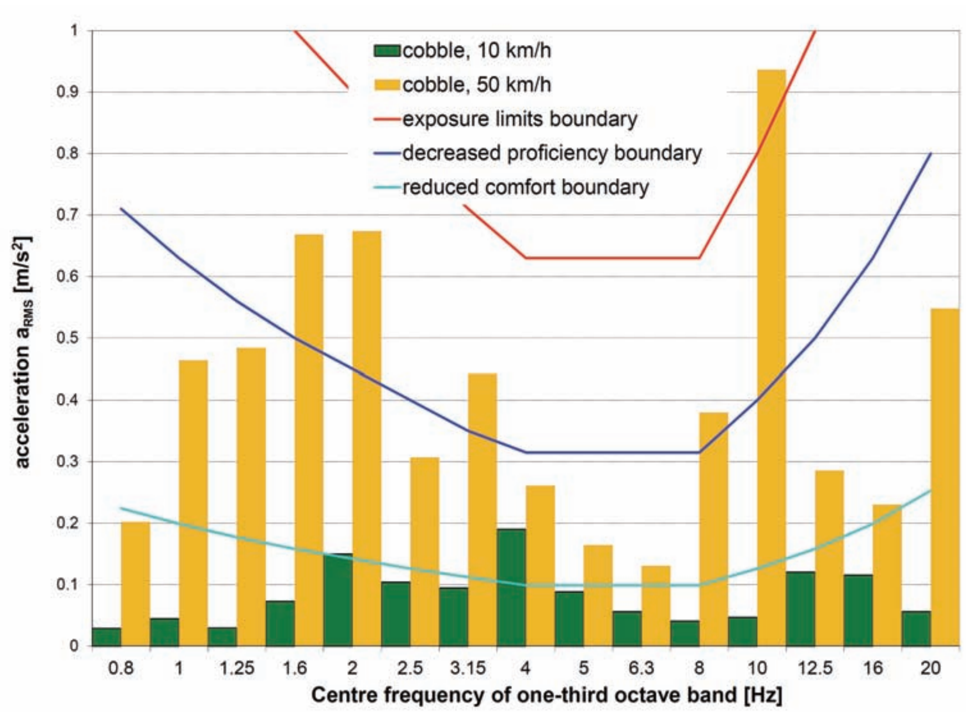

Fig. 7. The acceleration RMS value spectrum chart for driver seat on cobble surface

The charts for the vertical accelerations for the centre of mass and the driver's seat, at the speed of 40 km/h, for a single irregularity (the triangle prism), are shown in Figure 8. As for the passages on various road surfaces (asphalt, cobble, gravel, unsurfaced), it may be observed that the extreme values of the accelerations and the standard deviation are much higher for the driver than for the centre of mass. Maximum acceleration of the centre of mass is 5.47 m/s^2 at the minimum is –5.74 m/s^2. For the driver's seat the values are 10.96 and –13.83 m/s^2 respectively. The setting-up for extreme accelerations for the other vehicle speeds, taking into consideration the accelerations for the floor under the driver's seat, is shown in Table 3. The analogous setting-up for the passages over a single obstacle with a cosine profile is shown also in Table 3. The vertical accelerations for the centre of mass are signed with SM symbol, the accelerations for the driver's seat are signed with K, and the vertical accelerations for the floor under the driver's seat — with PK.

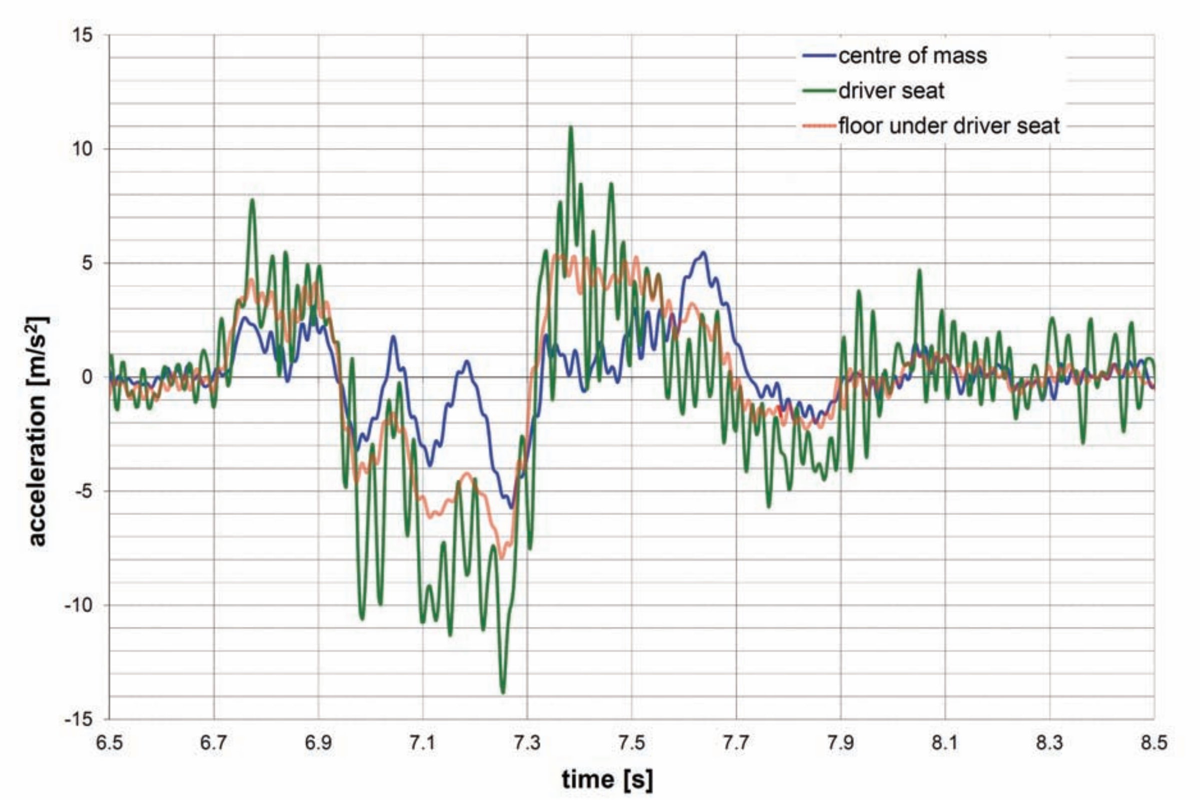

Fig. 8. Time chart of acceleration of centre of mass, driver seat and floor under driver seat for single irregularity (the triangle prism)

Tab. 3. Statistical summary of acceleration values for a single irregularity

		The triangle prism profile			Cosine profile		
Velocity [km/h]	External values	SM [m/s²]	K [m/s²]	PK [m/s²]	SM [m/s²]	K [m/s²]	PK [m/s²]
10	Max	1.69	2.66	1.69	1.51	1.45	1.48
	Min	-1.26	-3	-1.36	-1.1	-1.44	-2.02
20	Max	2.8	4.69	2.87	2.97	3.95	2.48
	Min	-3.14	-6.67	-3.58	-2.65	-4.37	-3.23
30	Max	4.42	11.75	3.56	3.42	4.51	3.16
	Min	-3.58	-7.75	-5	-3.24	-5.01	-4.27
40	Max	5.47	10.96	5.36	3.43	4.8	4.66
	Min	-5.72	-13.83	-7.93	-3.98	-5.24	-4.44
50	Max	7.21	22.28	6.89	4.43	5.53	4.31
	Min	-6.96	-14.5	-9.06	-3.65	-4.72	-6.05

The road availability limited the scope of the experimental research. On this account (and for the third persons' safety during the tests) maximum speeds were limited. Within the framework of the research the simulations for wider speed ranges were made. Example results for the very good quality asphalt surfaces are shown in Figure 9. The comfort boundary was not exceeded what indicates comfortable driving conditions. The simulation tests within a wider range will be presented in a separate paper.

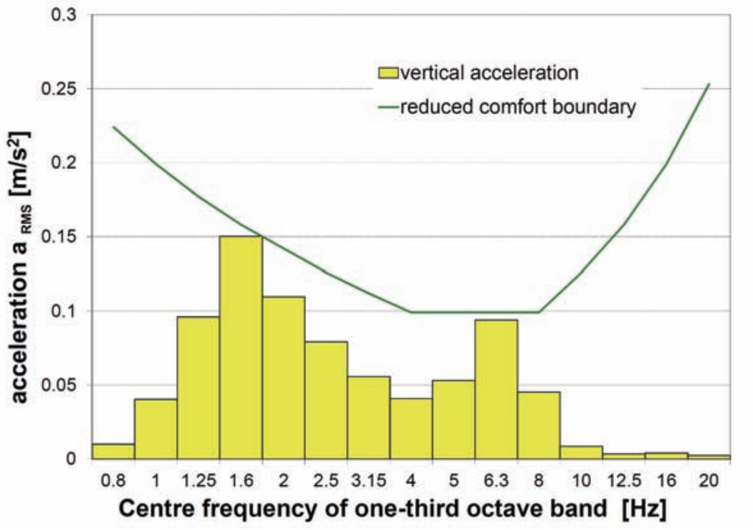

Fig. 9. The acceleration RMS value spectrum chart for driver seat – simulation, parameters: G_w=0.000006 m^3, w=2.18

3. Final Conclusions

On account of the test limitation to a single personnel carrier the tests were the diagnostic ones. In order to get more information about the dynamic impacts on the personnel carrier crew it is recommended to test several vehicles of every carrier type. However, the test results analysis make it possible to formulate the following conclusions:

- The personnel carrier provides a high driving comfort during driving on the good quality asphalt surfaces.
- During the personnel carrier movement on the poor quality asphalt surfaces RMS values of accelerations are much higher than for the good ones. The comfort boundary exceeding takes place already at the speed of 20 km/h. For the higher driving speeds the fatigue-decreased proficiency boundary exceeding takes place, too.
- For the cobble surfaces the fatigue-decreased proficiency boundary exceeding already takes place at the speed of 20 km/h. Along with the speed increase RMS values increase too, and at the speed of 50 km/h the values exceed the exposure-limit boundary.
- When the personnel carrier drives on the poor surfaces (the unsurfaced roads — the testing ground) the dynamic loads with the values exceeding the fatigue-decreased proficiency boundary are being generated, what negatively influences the driving comfort.

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