ISSN: 1231-4005
e-ISSN: 2354-0133
DOI: 10.5604/12314005.1216443

ASSESSMENT OF THE POSSIBILITY OF CARRYING PEOPLE INSIDE MILITARY FIELD WORKSHOPS

Zdzisław Hryciów, Piotr Rybak, Józef Wysocki
Andrzej Wiśniewski, Bogusław Michałowski

Military University of Technology
Kaliskiego Street 2, 00-908 Warszawa, Poland
tel.: +48 261837403, fax: +48 261837370
e-mail: zdzislaw.hryciow@wat.edu.pl, piotr.rybak@wat.edu.pl, jozef.wysocki@wat.edu.pl
wisniewski.andrzej@wat.edu.pl, boguslaw.michalowski@wat.edu.pl

Abstract

Military vehicles are used less intensively than the civil ones, and many types of the vehicles used by the army are stored for a long time. Therefore, this type of vehicles can be used even for a dozens of years. Due to the constant development of technology, used armament and military equipment has to be adjusted to current needs. The above applies also to recovery vehicles, including field workshops. This work analyses the level of safety and comfort of the crew of the modified field workshop (Sarna II) when the vehicle is moving under various conditions. The scope of improvement included two seats inside workshop for the transportation of the crew members.

Experimental research involved measuring the accelerations on the seats of the crew and the noise inside the vehicle body. The assessment was conducted on the basis of the highest value of 8-hour of the exposure to the whole body vibrations A(8). The accelerations acting on the seats were determined mainly by the kind of the road, its roughness and the speed of the vehicle. The occupational risk connected with the exposure to the mechanical vibrations was in most cases assessed to be low or moderate. The risk was assessed to be high only when the vehicle was moving on the dirt road. Results of experimental researches indicated that passengers travelling in the body of Sarna II workshop, mounted on the underbody of STAR 266M2 vehicle, have ensured proper conditions of transport, both in terms of exposure to mechanical vibrations and to the noise.

Keywords: *noise, vibration, military field workshop, experimental researches, risk assessment*

1. Introduction

Modern battlefield is constantly changing – this is why every new generation of armament and military equipment is an attempt at improvement. New generations of armament are developed both by improving the already existing constructions and by designing new ones. A piece of military equipment is usually improved many times because it is used for many years. The scope of improvement may include perfecting all the combat features (comprehensive improvement) or only the selected ones (partial improvement). The process of improvement involves not only military vehicles and elements of armament but also the equipment used by the military units responsible for the logistics to ensure proper operation of the basic armament [1].

Machines and tools used to operate and repair the armament are one of the basic factors facilitating the effectiveness of the process of keeping the systems of weapons in running condition. While dealing with the military equipment, it is necessary to apply technical solutions that are very different from those used in the other areas of economy. Units of military logistics should be equipped with proper equipment for operating and repairing the armament, especially: mobile workshops, recovery vehicles, technical tents, mobile workshops for diagnostics and repairing subassemblies and sets of tools or materials used for repairing.

In most cases, the body of various types of workshops is mounted on STAR 266 off-road lorries, which contributes to the effectiveness of service and repair field workshops. Polish army usually uses Sarna I and II bodies. Sarna II is a vehicle body of new construction design, which is sealed and equipped with a fan filter unit. Sarna II is a construction used for deploying the equipment and it is designed in a manner that makes it possible for it to be quickly unloaded from the underbody, and to deploy it on a stable ground, on special supports.

In case of some types of workshops, it may be necessary to increase the number of personnel. Therefore, it is necessary to mount extra seats inside the vehicle body, making it possible to carry passengers outside the cabin of the car. In this case, it is important to ensure the safety of the passengers and make the seats relatively comfortable, so that the passengers are not too tired, which would have a negative impact on the ability of the personnel to perform their tasks.

Therefore, the main goal of the work is to assess the safety and comfort of the crew travelling inside the vehicle body of Sarna II workshop. The analysis is based on the results of experimental research.

2. Research object and methodology

The object of the research (Fig. 1) is Sarna II workshop, deployed on STAR 266M2 underbody along with an electric power generator on D 622 one-axle trailer. Two passenger seats (for the crew of the workshop) were mounted inside the vehicle body.

Fig. 1. Star 266M2 with Sarna II workshop

The tests were conducted in a body of a workshop, equipped with the necessary devices, tools and seats. Fig. 2 depicts the inside of the workshop. For the purpose of the work, the following symbols were assigned: seat no. 1 is the seat at the back of the body, seat no. 2 is the seat at the door of the body of the workshop. It is worth emphasizing that the tests of the military vehicles should not cover only the general requirements, but also the guidelines of applicable military standards [5, 6].

The objective of research was to assess the safety and comfort of the crew travelling in S1AB01 and S1MED01 seats, manufactured by INTAP, mounted in the body of the workshop, as well as the dynamic loads acting on the crew and on the equipment of the workshop.

The tests were conducted with control and measurement instruments, including three-axis seat acceleration sensors, placed on the seats occupied by the members of the workshop crew. The measurements of the level of noise to which the crew members were exposed inside the workshop body were conducted with 1613 sound level meter, manufactured by Brüel & Kjær. The meter was placed between the seats, at the level of the heads of sitting passengers.

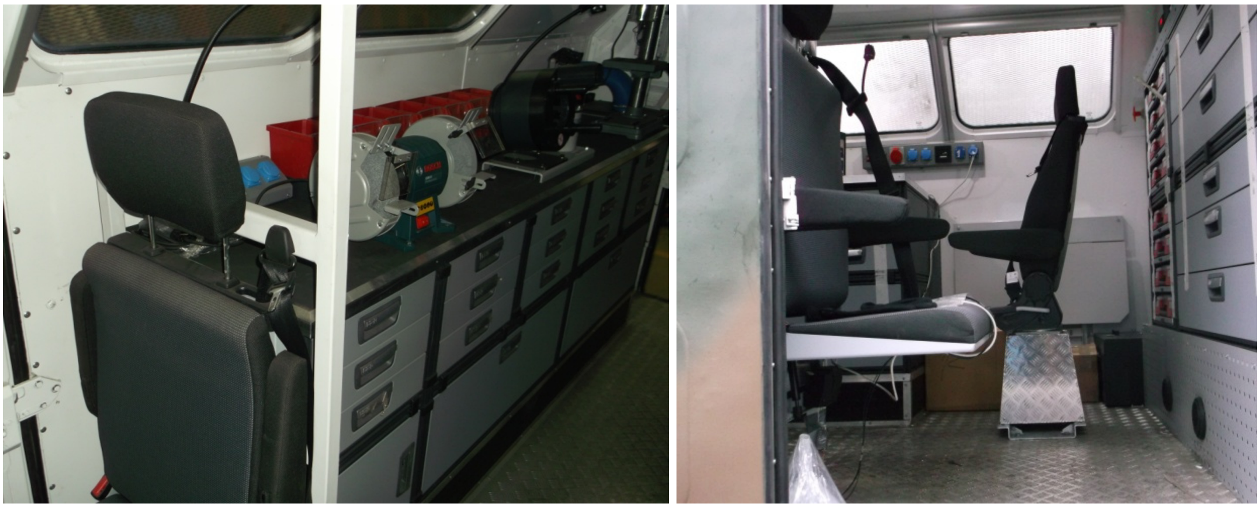

Fig. 2. Interior of Sarna II workshop

The nuisance of the vibrations generated by vehicles is highly subjective, therefore it is difficult to determine reasonable limits of exposure. The assessment of the exposure to the whole body vibrations was conducted on the basis of the highest value of 8-hour exposure among the exposures measured in three directions: max{$A_x(8)$, $A_y(8)$, $A_z(8)$}. A_l for each direction is calculated with equations [2, 4]:

$$A_l(8) = k_l \cdot \sqrt{\frac{1}{T_o} \cdot \sum_{i=1}^{n} a_{wli}^2 \cdot t_i}\ , \tag{1}$$

where:
n – number of activities performed during the exposure to the vibrations,
i – number of the activity performed during the exposure to the vibrations,
l – direction of the vibrations (x, y i z),
$k_x = k_y = 1.4$, for x and y directions; $k_z = 1$ for z direction,
ti – duration of activity number i,
a_{wli} – adjusted value of the vibration acceleration, measured in x, y and z directions for the activity number i, performed during the exposure to the vibrations.

According to the Regulation [7], the exposure action value (EAV) for whole body vibrations is 0.5 m/s^2, whereas the daily exposure limit value (ELV) A(8) vibrations is 0.8 m/s^2 [8]. When the value exceeds the EAV, the employer is obliged to undertake the actions specified in the provisions of applicable law in order to reduce the occupational hazard connected with the vibrations. The assessment of the occupational risk connected with the exposure to mechanical vibrations involves mainly comparing the values of ELV at the workplace to the measured values of exposure. The risk is usually calculated as the ratio (k) of the measured value to the applicable ELV value [2, 4]:

$$k \le 0.5, \qquad \text{low risk,}$$
$$0.5 < k \le 1, \qquad \text{moderate risk,}$$
$$k > 1.0, \qquad \text{high risk.}$$

The ratio is calculated with the following equation:

$$k = \frac{A(8)}{A(8)_{dop}}. \tag{2}$$

ISO 2631 [3] international standard can also help in the assessment of the exposure when calculating the distribution of the effective acceleration in various frequency ranges.

3. Test results

The research was conducted with the vehicle moving on various types of road. The tests included an asphalt road, a gravel road and a dirt road in average condition. The measured changes in values over time served as the basis to assess the level of permissible vibrations.

Figure 3 depicts exemplary changes of vertical accelerations over time, measured on seats no. 1 and 2, with the vehicle moving at 20 km/h on the dirt road. The changes over time were very similar, which was due to the fact that the seats are placed in a similar distance in the direction longitudinal towards the centre of gravity. The above is caused by the fact that the seats are placed in a similar distance in the direction longitudinal to the centre of the mass. The minor differences observed in changes over time were caused mainly by displacement of seat no. 2 towards the side of the body of the vehicle. Due to the above, the angular displacement of the body of the vehicle with regard to the longitudinal axis in another factor determining the value of the accelerations. However, it is important to stress that the differences are visible mainly with the vehicle moving on the roughness causing this type of displacement (mainly dirt roads). On the asphalt road, the differences between the changes of the accelerations on the two seats were even smaller.

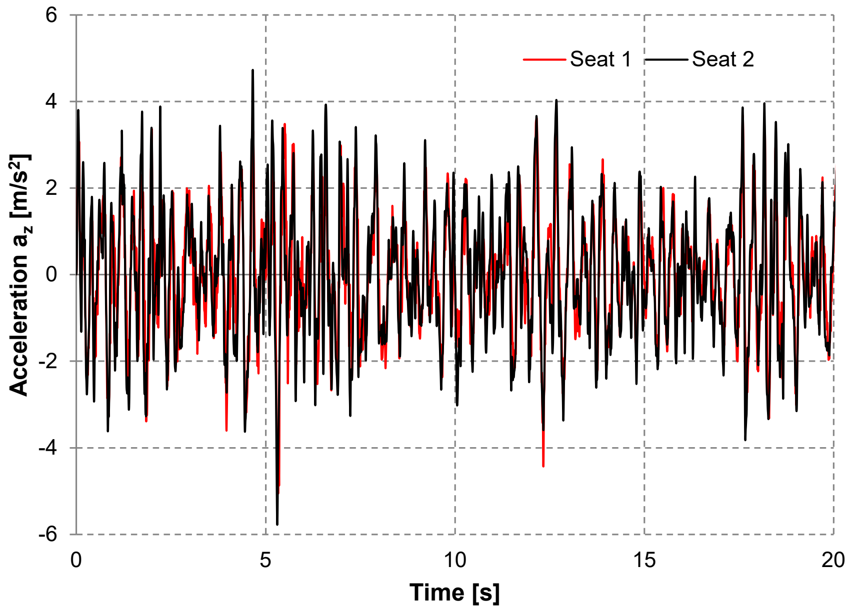

Fig. 3. Vertical accelerations on seats – dirt road, v = 20 km/h

The main factors determining the value of the accelerations acting on the seats were the type of the road, its roughness and the speed of the vehicle. In the majority of analysed situations, increasing the speed of the vehicle resulted in the increase in the value of the accelerations acting on the seats. However, significant differences were observed at 40 km/h. Fig. 4 depicts the changes of the vertical accelerations over time on the seat no. 1 with the vehicle moving on the same stretch of the asphalt road at two different speeds, 40 and 60 km/h. We clearly see that the increase in speed resulted in decreased value of the accelerations. Another finding is that at 40 km/h one of the frequencies of the vibrations has the biggest impact. The above is confirmed also by frequency analysis of the signals.

Figure 5 depicts the charts of power spectral density of the accelerations for the signals presented above. At 40 km/h, the component of 3 Hz frequency is the dominant value. The distribution for the higher speed is different, there is no such clear dominant value. At 3 Hz frequency, the value of power spectral density of accelerations is about 14 times lower, due to resonant vibrations and forces that make the elements of the vehicle body vibrate. The same result was observed also in the vehicle moving on the gravel road.

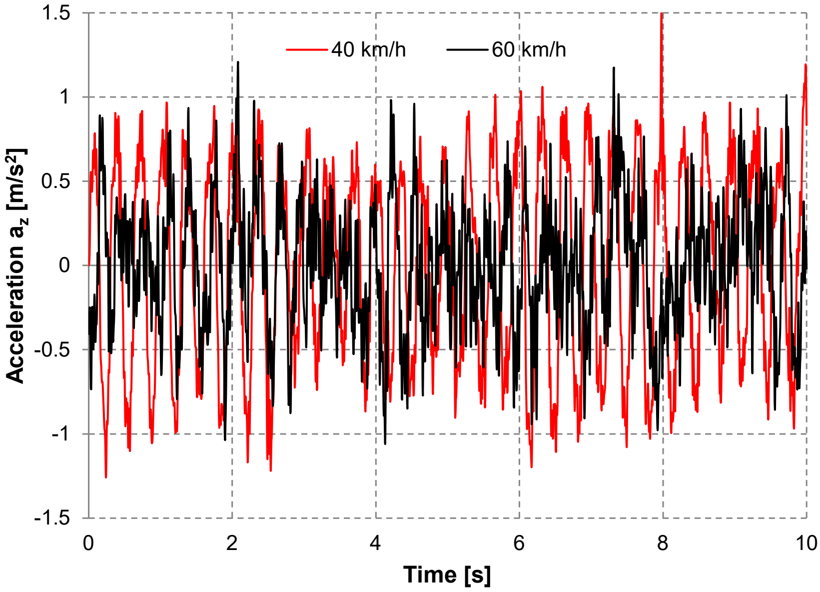

Fig. 4. Vertical accelerations on seat no. 1 – asphalt road, v = 40 and 60 km/h

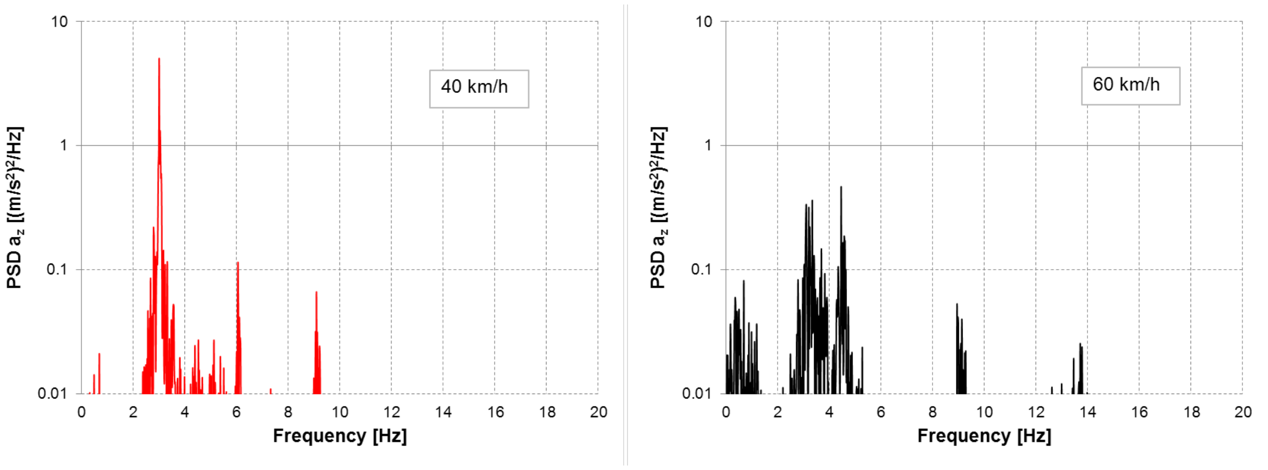

Fig. 5. Power spectra density of the *accelerations on seat no. 1 – asphalt road, v = 40 and 60 km/h*

The effects of the phenomenon described above can be observed also on the charts presenting the distribution of effective accelerations in various 1/3 octave bands of the accelerations. Fig. 6 depicts the result of acceleration analysis based on ISO 2631 standard. The chart depicts also the permissible values, determining the fatigue-decreased proficiency boundary and an exposure limit. We clearly see the vibrations significantly exceeding the fatigue-decreased proficiency boundary in the band of centre frequency of 3.15 Hz. In this band, the effective value of accelerations is for 40 km/h speed twice as high as for 60 km/h. In the case of the neighbouring bands, most important when it comes to the perceived intensity of the vibrations (i.e. 4 vs. 8 Hz), higher values were recorded for the higher speed. However, those values are distributed in a wider range of frequency and the fatigue-decreased proficiency boundary was not exceeded. Is also has to be emphasized that an exposure limit was not exceeded in any of the analysed testing situations.

Table 1 presents a summary of the results of the measurement of vibrations and noise for all of the analysed situations. The highest load of vibrations was recorded on seat no. 2, with the vehicle moving on the dirt road. Slightly lower values were recorded on seat no. 1. However, the daily exposure to vibrations exceeded 0.8 m/s^2 for both of the seats, and the occupational risk connected with the exposure to mechanical vibrations was assessed to be high. Greater load acting on a human sitting in seat no. 2 can be assumed also on the basis of the results of the tests with the vehicle moving at various speed on the asphalt road. In the case of seat no. 1, the value of daily exposure A(8) was not higher than 0.4 m/s^2 for all the values of speed, therefore the risk is assessed to be low. In case of seat no. 2, the level of risk turns into moderate above 50 km/h.

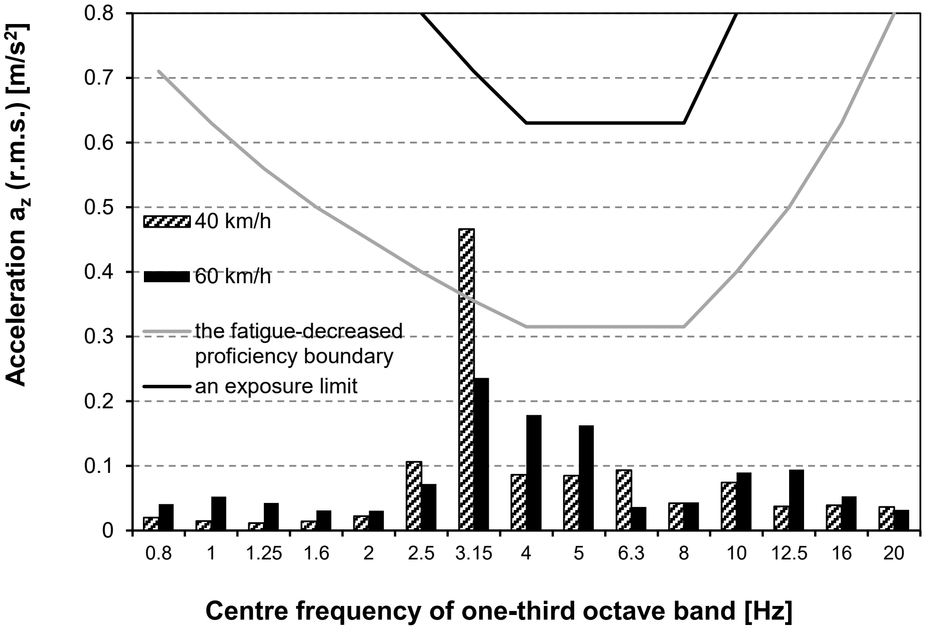

Fig. 6. RMS of vertical acceleration on seat no. 1 – asphalt road, v = 40 and 60 km/h

Tab. 1. A summary of the results of the measurement of vibrations and noise

No.	Kind of road	Velocity [km/h]	Seat 1				Seat 2				Noise level [dB(A)]
			A(8) [m/s^2]	k	risk	Te[h]	A(8) [m/s^2]	k	risk	Te[h]	
1	Asphalt road	20	**0.202**	0.25	low	8	**0.233**	0.29	low	8	68
2		30	**0.205**	0.26	low	8	**0.245**	0.31	low	8	70
3		40	**0.427**	0.53	low	8	**0.449**	0.56	moderate	8	78
4		50	**0.371**	0.46	low	8	**0.427**	0.53	moderate	8	71
5		60	**0.388**	0.49	low	8	**0.417**	0.52	moderate	8	76
6		70	**0.395**	0.49	low	8	**0.456**	0.57	moderate	8	77
7	Gravel road	30	**0.399**	0.50	low	8	**0.498**	0.62	moderate	8	72
8		40	**0.541**	0.68	moderate	6.83	**0.641**	0.80	moderate	4.87	78
9		50	**0.502**	0.63	moderate	7.95	**0.588**	0.74	moderate	5.79	73
10	Dirt road	20	**0.828**	1.04	high	2.92	**0.996**	1.25	high	2.02	74

On the asphalt road, the exposure action value was not exceeded for general vibrations. Therefore, there is no need to shorten the permissible time of exposition T_e. However, it is necessary to do so with the car moving on the gravel road at more than 40 km/h and on the dirt road.

The results of the noise measurement inside the vehicle body indicate that in each of the analysed situations the limit of permissible daily noise exposure was not exceeded. The highest noise level was recorded with the vehicle moving at 40 km/h both on the asphalt road and on the gravel road. The level reached the value of 78 db(A), due to the vibrations of the elements of vehicle body, which is confirmed by the recorded vibration measurements.

Figure 7 depicts the chart of the levels of A(8) daily exposure to whole body vibrations for each of the analysed situations. On the chart, the exposure action value (EAV) is also marked, as well as the daily exposure limit value (ELV).

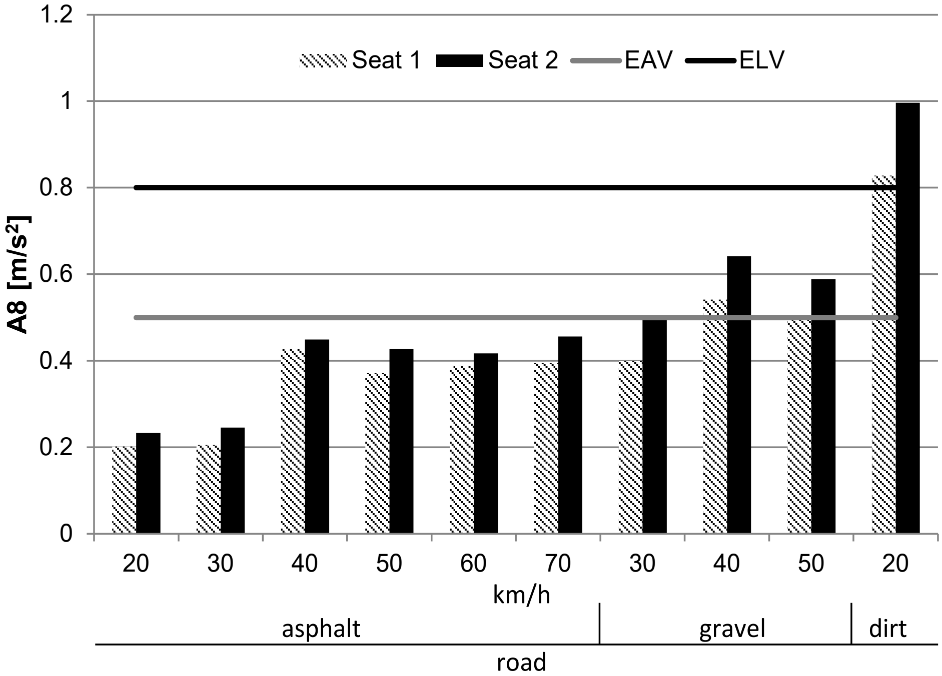

Fig. 7. The levels of daily exposure values to whole body vibrations on seat no. 1 and 2 – asphalt road, v = 40 and 60 km/h

4. Summary

Military equipment is used in a very unique manner. Military vehicles are used less intensively than the civil ones, and many types of the vehicles used by the army are stored for a long time. Therefore, this type of vehicles can be used even for a dozens of years. Due to the constant development of technology, used armament and military equipment has to be adjusted to current needs. The above applies also to recovery vehicles, including field workshops.

This work analyses the level of safety and comfort of the crew of the field workshop when the vehicle is moving under various conditions. The equipment of the workshop, deployed in Sarna II vehicle body, a property of the army, was improved. The scope of improvement included also mounting two seats for the transportation of the crew members.

Experimental research involved measuring the accelerations on the seats of the crew and the noise inside the vehicle body. The accelerations acting on the seats were determined mainly by the kind of the road, its roughness and the speed of the vehicle. In the majority of analysed situations, increase in the speed of the vehicle resulted in the increase in the accelerations. Significant differences were recorded for 40 km/h. At this speed, the level of exposure to vibrations A(8) was significantly higher than in the case of other values of speed. The occupational risk connected with the exposure to the mechanical vibrations was in most cases assessed to be low or moderate. The risk was assessed to be high only when the vehicle was moving on the dirt road. However, it is worth to emphasise that the members of the crew are not exposed to the vibrations for a long time. After being transported to the place of destination, they perform their work after the vehicle comes to a complete stop.

According to the research analysed, regardless of the conditions of use, travel speed and the kind of road (condition of the surface), recorded noise level does not exceed 78 dB(A), therefore it does not exceed the permissible value of 85 db(A). Due to the above, for the passengers travelling in the body of Sarna II workshop, mounted on the underbody of STAR 266M2 vehicle, proper conditions of transport are ensured, both in terms of exposure to mechanical vibrations and to the noise.

References

[1] Borkowski, W., Michałowski, B., Papliński, K., Rybak, P., Wysocki, J., *Modernizacja resorów samochodu ciężarowego STAR 1366 wyposażonego w zestaw artyleryjski BM-21*, VII Międzynarodowe Sympozjum Instytutu Pojazdów Mechanicznych WAT, Doskonalenie konstrukcji oraz metod eksploatacji pojazdów mechanicznych, pp. 43-52, Warszawa 1999.

[2] Kowalski, P., *Pomiar i ocena drgań mechanicznych w środowisku pracy według nowych przepisów prawnych*, Bezpieczeństwo pracy, 9, pp. 24-26, 2006.

[3] ISO 2631-1:1997 Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration – Part 1: General requirements.

[4] Materiały szkoleniowe, *Drgania mechaniczne zagrożenia i profilaktyka*, CIOP.

[5] NO-23-A002:2016, *Sprzęt wojskowy – Nadwozia pojazdów zabezpieczenia technicznego – Terminologia*.

[6] NO-23-A502, *Technika wojskowa – Badania wojskowych pojazdów mechanicznych*.

[7] Rozporządzenia Ministra Gospodarki i Pracy z dnia 5 sierpnia 2005 r. w sprawie bezpieczeństwa i higieny pracy przy pracach związanych z narażeniem na hałas lub drgania mechaniczne (Dz. U. 2005, nr 157, poz. 1318).

[8] Rozporządzenie Ministra Pracy i Polityki Społecznej z dnia 29 listopada 2002 r, w sprawie najwyższych dopuszczalnych stężeń i natężeń czynników szkodliwych dla zdrowia w środowisku pracy (Dz. U. 2002, Nr 217, poz. 1833).