11TH INTERNATIONAL SCIENTIFIC CONFERENCE
ON DEFENSIVE TECHNOLOGIES
OTEH 2024
Serbia, Tara, 9-11 October 2024

ASSESSMENT OF EXPOSURE TO PHYSICAL HAZARDS IN THE WORKING ENVIRONMENT DURING TESTING OF PROTOTYPES

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Abstract: *This paper presents only a part of the risks and harmfulness to which the employees working in Serbian MoD and especially in Technical Test Center are exposed during tests on new armaments and various other equipment under development. In addition to the results of noise and vibration measurements in the working environment at the training grounds and the airport, the risks during laboratory and experimental-exploitation tests in the field are presented. Noise and vibration as harmfulness effects were measured and evaluated according to the relevant criteria, while far more dangerous risks of working with prototypes are immeasurable, unpredictable and not included in the regulations.*

Keywords: *work environment, noise, vibration, risk assessment.*

1. INTRODUCTION

Activities in the army are characteristic of their specificity, numbers and diversity, as well as in civilian sector. The common motto of those employed in the army is respect for hierarchy and discipline as well as behavior in accordance with high moral values, which is often psychologically demanding and stressful. It is a known fact that being a soldier is one of the most stressful occupations, considering the factors of exposure to dangers, the expected level of mental and physical readiness and other specifics of military relations and life.

On the other hand, professional-technical staff, responsible for weapons and military equipment, are exposed to risks and dangers of the widest spectrum of harmfulness in the work environment: physical, mechanical, chemical, ergonomic, biological and previously stated psychosocial.

The strategic activity of preventing and reducing the occurrence of accidents is effective in certain domains such as military transport, but when performing many other tasks (and in order to successfully perform them), the exposure of the perpetrators to harm is inevitable.

The army is equipped with weapons and military equipment resources according to the model: own development, acquisition by license, procurement or donated final product, joint development with an international partner or a combined method of equipping. The advantages of own development from domestic sources are numerous: independence from external factors, industrial progress of the country, strengthening the scientific research resources, etc.

Armament and military equipment (from domestic production, imported or after general overhaul) are put into operational use and exploitation based on and after testing and quality assessment.

An important, experimental phase in the armament and military equipment domestic development is the construction and testing of prototypes or small test batches. Prototypes are only the basis for the development of the finished product, therefore many technical and functional characteristics are unpredictable, which is the reason for posible serious accidents during their testing. The aim of the examination is to verify the fulfillment of the set tactical-technical requirements and the compliance of the asset with the technical regulations of defense.

When adopting and introducing new assets into the military systems, the satisfaction of the fulfillment the requirements of ergonomics, human engineering and adaptation of the asset to man, so one can operate and work efficiently, successfully and with quality.

The Technical Test Center is authorized to conduct final (from domestic development), verification and homologation (finished domestic and foreign products) tests of armament and military equipment. The following are examined: weapons (classical, aviation, naval), all types of vehicles, aircrafts and ships (combat, non-combat, special), engineering machines, means of nuclear, biological and chemical protection and electronic

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DOI:10.5937/OTEH24034J

(telecommunication, optoelectronic, fire control) means. For the needs of all types of tests, special measurements are performed in the laboratory, polygon and field (trial and operational tests). The Technical Test Center provides services of special measurements and polygon and other tests at the request of customers outside the Army, in order to test and evaluate their quality.

2. EXAMINATIONS ON PHYSICAL DAMAGE AND ERGONOMICS

As a part of the complex testing of assets that are expected to enter the military use, the fulfillment of requirements for the protection of the environment and the working environment is also checked. Possible harms are being measured, and after processing and analyzing the results, an assessment of the fulfillment of requirements that follow the latest standards is given.

In this paper, as an example, the results of noise and vibration measurements during the testing of the following prototypes are presented: on the military training ground – wheeled self-propelled gun-howitzers, on the military airport - school plane, during field test operation - vehicles with a superstructure for military equipment and armored vehicles. The results were evaluated according to health and comfort criteria: for noise, the Rulebook on preventive measures for safe and healthy work with exposure to noise (based on EU directive ES/10/03 and ISO 9612 standard), for vibrations, the Rulebook on exposure to vibrations (based on ES /44/02 and ISO 2631, 5349).

An example of immeasurable ergonomic hazards and risks when working with heavy loads during laboratory field tests of static and dynamic characteristics is also presented.

2.1. Noise and vibrations in the working environment of a Wheeled Mobile Howitzer on a military training ground

Shot noise measurements from a 155 mm howitzer were made with a NetdB12 measurement system (made by 01dB Metravib from France) with 1/4" microphones (free field, type 46AE G.R.A.S).

The measurement places were in the driver's cabin, the commander's place and the gunner's place, where the microphones are directed towards the shooting direction, and at a height corresponding to the position of the crew member's head.

Figure 1. Test object at the military training ground

The measurement results (Table 1) are expressed in $dBC_{(peak)}$, the unit for high-energy impulse noise, as well as in $dBC_{(I)}$ related to impulse noise. Also an 1/3 octave noise analysis was also performed (Figure 1a).

Table 1. Noise levels of a 155 mm howitzer

Measuring point	Noise level $L_{peak,C}$ (dB)	Noise level $L_{impulse,C}$ (dB)
cabin	154.8	148
commander	158.5	149.6
gunner	159.6	150.9

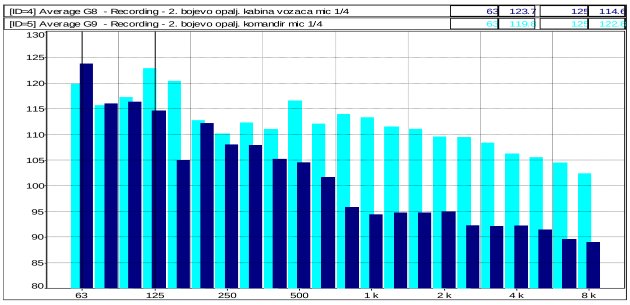

Figure 1a. 1/3 octave spectrum of firing at driver and commander position

Vibration testing when firing from a howitzer was performed with a dedicated vibrometer Maestro 01dB Metravib for workplace measurement, supported by software according to EC/44/02 and ISO 2631-1, 4, 5. The measuring device has a three-axis accelerometer built into the seat adapter to determine the vibrations transmitted to the whole body in the frequency range 0 ÷ 10,000Hz.

The results of triaxial vibration measurements are shown for the position of the gunner, from the point of view of the quality of health and comfort (Figure 2).

Whole body						
Quality	Health					
Body position	Seated					
Measurement location	Seat					
Type	aw					
Axis	X	Y	Z	Overall av	Overall A(8)	Exposure
Weighting	Wd	Wd	Wk			
Coefficient	1.4	1.4	1			
Level (m/s2)	1.52	0.70	5.87			
Corrected (m/s2)	2.12	0.97	5.87	6.31	5.87	8h
Warning level (m/s2)					0.50	3m29s
Maximum level (m/s2)					1.15	18m27s
Exposure level A(8) is above maximum level						

Type	Peak factor			
Axis	X	Y	Z	Max.
Peak factor	2.98	3.20	4.02	4.02
Peak factor is smaller than 9				
According to Standard 2631-1, A(8) assessment is recommended				

Type	VDV				
Axis	X	Y	Z	Max. VDVeq	Exposure
Weighting	Wd	Wd	Wk		
Coefficient	1.4	1.4	1		
VDV dose (m/s 1.75)	4.37	2.09	19.47		
Corrected (m/s 1.75)	6.12	2.93	19.47	19.47	5s
Warning level (m/s 1.75)				9.10	
Maximum level (m/s 1.75)				21.00	
VDV level is above warning level					

Whole body				
Quality	Comfort			
Body position	Seated			
Measurement location	Seat			
Type	aw			
Axis	X	Y	Z	Overall av
Weighting	Wd	Wd	Wk	
Level (m/s2)	1.52	0.70	5.87	6.10
2.00 m/s2 <= Aeq : extremely uncomfortable				

Figure 2. Vibration measurement report at the gunner's position according to criteria for health and comfort

2.2. Noise in the operating environment of a school plane at a military airport

In the working environment of the technical staff and crew of the school plane in ground mode, after warming up, the noise was measured with two directional 1/2" microphones (with the previously mentioned noise measurement system) at a height of 0.94 m, at a distance of 1.64 m from plane and at an angle of 90º and 45º placed left of the engine. The results are shown in Table 2.

Table 2. Noise level in the working environment around the school plane

Mode of work on the ground at:	*Equivalent level, fast* dB (A)	
	Measuring point of the microphone 45º	*Measuring point of the microphone* 90º
1800 rev	109.3	103.5
2200 rev	117.2	112.6
2400 rev	121.7	117.8
2700 rev	124	121
Add gas slowly (1200÷2610) rev	122.2	118.6
Checking the magnet 2 times with holding the work one of them for 10 seconds	114.5	108.9
Checking the regulator - easy	113.6	108.9

2.3. Noise and vibrations in the superstructures of military vehicles and armored vehicles during off-road driving

During the testing of military vehicles (mobile weapons and military equipment) in real conditions of exploitation, numerous parameters related not only to functionality, but also to working conditions and environmental protection are measured.

Of the many measurement results that affect health and comfort, the part related to noise and vibrations when driving in the superstructure of a vehicle with military telecommunications equipment (Table 3) and when driving in an armored military vehicle (Table 4) is shown.

Table 3. Results of oscillations measurements and noise at the operator's place in the cabin of a vehicle with a superstructure while driving at speeds adapted to the tracks

Track type	*Eq. triaxial accelerat. for comfort* a_v **(m/s²)**	*Comfort rating*	*Eq. triaxial speed up for health* a_v **(m/s²)**	*Eq. noise level in the cabin* **(dB(A))**
wasteland	*1.40*	*very uncomf.*	*1.72*	78.4
macadam	*1.26*	*very uncomf.*	*1.47*	79.8
asphalt	*0.86*	*uncomf.*	*0.95*	77.5

Table 4. Results of noise measurements inside an armored vehicle during off-road driving at the driver's (passenger's) and crew's places

Track type	*Speed* (km/h)	*Eq. noise level* (dB(A)) driver / crew
asphalt	50	84.4 / 83.7
	60	85.6 / 85.1
wasteland	30	82.3 / 82.1
	40	86.1 / 85.4
plain macadam	30	81.7 / 80.8
	40	85.7 / 83.4
	50	84.0 / 83.2

2.4. Risks and dangers during experimental tests of static and dynamic characteristics of movable assets of armament and military equipment in laboratory and field conditions

Experimental methods of testing the characteristics of the support system and stability (load distribution and center of gravity of the dynamic system) of various types and types of military vehicles of various types and purposes are extremely risky for drivers and researchers and all other test participants too. Vehicles (wheelers, crawlers and amphibians) are lifted and overturned in laboratory conditions, in the field they overcome obstacles and limit angles of lateral, frontal and rearward inclination, while in strong rivers amphibians are tested for swimming.

The mentioned vehicles weigh up to 40 tons, so it can be assumed what kind of dangers they pose and what kind of accidents can happen. Regulations do not regulate all situations that can happen realistically and unexpectedly.

One of the common measurements of the center of gravity is shown in Figure 3, while Figure 4 shows the overcoming of the front slope obstacle in off-road conditions.

Figure 3. Working under a hanging vehicle - testing the center of mass

Figure 4. Vehicle tracking when moving down the front boundary slope

3. CONCLUSION

From the presented results of measurements at the training ground when firing from howitzers, it can be seen that the gunshot noise levels (expressed in dBC$_{(peak)}$) at the crew positions are greater than 140 dBC$_{(peak)}$.

According to the EU Directive 2003/10/EC on minimum requirements for noise exposure, the limit value to which an employee can be exposed using personal protective equipment for impulse noise is 140 dBC$_{(peak)}$, and according to the Republic of Serbia Rulebook on preventive measures for safe and healthy work at exposure to noise, the limit value of exposure to noise is 137 dBC$_{(peak)}$, so the negative assessment of the noise in question is obvious. From the analysis of 1/3 octave spectra of the subject impulse noise, it can be seen that the characteristic frequencies are in the low-frequency range corresponding to large-caliber ammunition. Also, from the reports of the measured vibrations in the howitzer crew positions, extreme discomfort and time in that working position of 3.5 minutes to the warning value (or 18.5 minutes to the limit value) of health exposure can be seen.

The measured equivalent noise levels in the environment of the school plane during ground operation mode (airport) significantly exceed the limit value of daily exposure to noise of 85 dB(A) prescribed by the aforementioned noise regulations from the point of view of hearing protection from damage.

According to the measurement results, the oscillations in the cabin of the vehicle with a superstructure during off-road driving on asphalt are in the domain of uncomfortable driving, while when driving on wasteland and plane macadam road, they are in the domain of very uncomfortable driving. In relation to the criteria for harm to health, driving this off-road vehicle should be time-limited from the aspect of oscillations as in Table 3. The analysis of the measured noise in the cabin with military equipment (is in the range of 77.5 ÷ 79.8 dB(A)) on asphalt and macadam results in a spectrum that is below the limit norm NR80 (only physical work without mental strain is possible). Also, the noise levels measured in the armored vehicle in real operating conditions when driving on all types of tracks exceed the action (80 dB(A)) and mostly the limit level (85 dB(A)) of noise exposure, while the noise spectrogram in the closed space of the vehicle corresponds to the classification curve NR90, when only physical work is possible without mental strain.

The subjective feeling of discomfort while driving from the aspect of oscillations and noise is much worse than the measurement results due to the effect of combined health hazards (stuffiness, lack of air conditioning, oscillations with impacts, noise or screeching from numerous racks with equipment, etc.).

The exposure limits given by unilateral directives are not sufficient for such workplaces. Also, you should keep in mind the problem of not being able to use ear protectors while driving due to monitoring the road situation.

All ergonomic harms cannot be predicted and counted, nor can they be defined by criteria. As these are assets under development, prototypes and various other samples which characteristics are still being tested, the probability of unpredictable and undesirable events is very high.

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Правилник о начину и поступку процене ризика на радном месту и у радној околини ("Службени гласник РС" бр. 30/10).