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ASSESSMENT OF OCCUPATIONAL VIBRATIONS ON INLAND WATERWAY CRAFTS – A PILOT STUDY

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Shipping and fishing are among the sectors of the economy which are characterised by particularly inadequate working conditions and, as a consequence, crews belong to the group of workers whose health and lives are particularly vulnerable. Inadequate working conditions are one of the two main sources of job dissatisfaction for this professional group. According to the literature data, noise and vibrations dominate in the group of negative factors of the working environment on vessels. As part of the project, the aim of which is to carry out a comprehensive assessment of environmental hazards and nuisances on selected vessels, pilot studies on working conditions on inland waterway crafts were carried out. These pilot studies included measurements and assessment of physical environmental factors, i.e. occupational vibrations, occupational noise and microclimate, on the following inland waterway crafts: a police boat, a rescue boat and a tourist boat. In the case of vibrations measurements, four parameters were determined: unweighted r.m.s. vibration acceleration value, frequency-weighted r.m.s. vibration acceleration value, daily exposure to whole-body vibration and daily exposure to hand-arm vibration. The highest vibration acceleration values were recorded on the police boat. But the assessment of whole-body vibrations and hand-arm vibrations in relation to permissible values specified for workplaces did not show any exceedances on the tested boats. The paper presents the detailed results of the measurements and the assessments of vibrations on the tested inland waterway crafts.

Keywords: vibration, workplace, inland waterway craft

1. Introduction

Shipping and fishing are among the sectors of the economy which are characterised by particularly inadequate working conditions and, as a consequence, crews belong to the group of workers whose health and lives are particularly vulnerable. According to data published in [1], among the approximately 28 million fishermen worldwide, about 24,000 of them lose their lives annually while performing their profession. Meanwhile, the results published in [2] indicate that 85% of maritime accidents on ships are caused by crew errors due to excessive physical strain, including inappropriate working conditions. Similar data are given in many publications; for example, in [3] states that there is a strong belief among scientists that humans contribute to around 80% of accidents in navigation. This is confirmed by the latest data published by the Statistics Poland characterizing maritime accidents and incidents that occurred on Polish vessels in the period 2018-2021 [4]. According to this data, the number of maritime accidents is increasing, with human factors being the main cause. For example, in 2021, out of 63 maritime accidents and incidents registered by the State Commission for the Investigation of Maritime Accidents, human factors were the cause of as many as 45 of these accidents and incidents.

One of the two fundamental sources of job dissatisfaction for crews of vessels is working conditions. According to literature data, among the negative factors of the working environment on vessels, noise and mechanical vibrations as well as extreme temperatures and relative humidity, especially in engine rooms, dominate. Therefore, for a comprehensive assessment of the professional exposure of employees employed on vessels, it is important to analyse the factors occurring in this specific work environment. Such analysis should encompass both physical factors, whose impact raises much concern, such as noise, mechanical vibrations, electric lighting, magnetic fields, variable climatic conditions, as well as psycho-social working conditions, which also significantly affect well-being, work capacity, and the safety and health of workers, including their quality of life.

In connection with the above, the Central Institute for Labour Protection – National Research Institute has undertaken the implementation of a project aimed at conducting a comprehensive assessment of hazards and environmental burdens on selected inland waterway crafts, as well as port, and coastal vessels, affecting both work safety and the quality of life of workers. Among the factors under investigation there are vibrations, which were measured on selected inland waterway crafts as part of pilot studies.

Vibrations acting on the human body can induce many complex phenomena. They are related both to the nervous conduction of vibrations as a stimulus and to the body's reaction as a mechanical system [5]. In the case of inland waterway crafts, individuals aboard have no direct influence on the sources of vibrations and perceive vibrations from the substrate caused by various types of equipment and components (including propulsion systems, power generators, control devices, etc.), as well as vibrations resulting from the movement of vessels under the influence of waves on water bodies. Such vibrations are classified as whole-body vibrations affecting the entire body of the exposed person. When handling control devices, auxiliary equipment, or hand tools, the vibrations are transmitted to the hand-arm system.

The results of the above mentioned vibrations measurements at workstations on inland waterway crafts are described in the subsequent part of this paper.

2. Test method

Vibrations measurements on inland waterway crafts were conducted with the aim of assessing the impact vibrations on the health of individuals on board. Therefore, the purpose of the measurements was to determine the parameters characterizing the mechanical vibrations occurring at the workstations. The measurements were taken at measurement points located at the assessed workstations.

The measured parameter characterizing vibrations was vibration acceleration. Additionally, the measured parameters included acceleration spectra in three mutually perpendicular directions, which could be used to identify vibration sources and select potential exposure reduction measures. The measurements were carried out in accordance with the methods defined in the following standards: PN-EN 14253+A1:2011 (in the case of whole-body vibrations) [6], PN-EN ISO 5349-1: 2004 and PN-EN ISO 5349-2: 2004 (in the case of hand-arm vibrations) [7, 8]. Additionally, the vibration assessment method specified in the ISO 20283-5:2016 standard [9] was applied.

The measurement system consisted of the following instruments complying with the requirements of the PN-EN ISO 8041-1:2017 standard [10]:

- 3 accelerometers type 4348 (Brüel & Kjær),
- a triaxial accelerometer type 4504-A (Brüel & Kjær),
- a triaxial accelerometer type 2560 (Endevco),
- 2 charge amplifiers, type 2692 (Brüel & Kjær),
- a multichannel analyzer system PULSE with 6-channel input module Type 3050-A-060 (Brüel & Kjær).

3. Test objects

The test objects were the workstations of steersmen located on three inland waterway crafts: a police boat, a rescue boat, and a tourist vessel. At each of the tested workstations on inland waterway crafts, one measurement point was located on the seat (for measurements of whole-body vibrations), and the second point was on the steering wheel (for measurements of hand-arm vibrations).

4. Results

The recorded vibration signals were analysed using the PULSE system. Whole-body vibrations were analysed in the frequency range of 0.5 – 400 Hz, while hand-arm vibrations were analysed in the frequency range of 5 – 1600 Hz.

According to the used test methods, the following parameters characterizing exposure to vibrations were determined: daily exposure to whole-body vibrations $A(8)_{WB}$ and daily exposure to hand-arm vibrations $A(8)_{HA}$. The assessment of the determined daily exposures was conducted based on the permissible values specified in the Regulation of the Minister of Family, Labour and Social Policy of 12 June 2018 on the highest permissible concentrations and intensities of harmful factors for health in the workplace environment [11]. According to this Regulation, the permissible value of the daily exposure to whole-body vibrations is 0.8 m/s^2 and the permissible value of the daily exposure to hand-arm vibrations is 2.8 m/s^2.

In addition, based on the recorded signals, an evaluation of vibrations was also carried out according to the methodology described in ISO 20283-5:2016. It includes, among others, the so-called acceptable values, which form the basis for evaluating vibrations corrected with the WM filter, acting on individuals aboard vessels. In the case navigation bridges and engine control rooms, the guideline values of acceptable vibration are as follows: 5.0 mm/s and 179.0 mm/s^2.

The detailed results of the whole-body vibration measurements and of the hand-arm vibration measurements at the tested workstations on the police boat are presented in Table 1 and Table 2 respectively. And the results of the vibrations measurements on the police boat in relation to acceptable values (given in ISO 20283-5:2016) are presented in Table 3.

Table 1: Results of the whole-body vibration measurements on the police boat.

Action	Frequency-weighted r.m.s. vibration acceleration value a_{wi} [m/s^2]			Exposure time [min.]	Daily exposure (the largest direction component) $A(8)_{WB}$ [m/s^2]
	X-direction component	Y-direction component	Z-direction component		
Mooring	0.04	0.05	0.05	10	$A_Z(8)_{WB} = 0.17$
Patrol speed	0.07	0.07	0.07	60	
Maximum speed	0.18	0.20	0.24	30	
Maneuvering speed	0.07	0.10	0.20	90	
Maneuvering speed (big waves)	0.15	0.21	0.43	50	

Table 2: Results of the hand-arm vibration measurements in accordance on the police boat.

Action	Frequency-weighted r.m.s. vibration acceleration value a_{wi} [m/s^2]			Exposure time [min.]	Daily exposure $A(8)_{HA}$ [m/s^2]
	X-direction component	Y-direction component	Z-direction component		
Mooring	0.92	0.57	0.58	10	0.87
Patrol speed	0.38	0.19	0.18	60	
Maximum speed	1.47	0.66	0.98	30	
Maneuvering speed	0.35	0.22	0.23	90	
Maneuvering speed (big waves)	1.86	0.81	0.59	50	

Table 3: Results of the vibrations measurements in accordance with ISO 20283-5:2016 on the police boat.

Action	Frequency-weighted r.m.s. vibration acceleration value a_{wi} [m/s^2]			Exposure time [min.]	Overall frequency-weighted r.m.s. vibration acceleration value (the largest direction component) [m/s^2]
	X-direction component	Y-direction component	Z-direction component		
Mooring	0.04	0.05	0.05	10	a_{wz} = 0.35
Patrol speed	0.06	0.06	0.12	60	
Maximum speed	0.18	0.19	0.30	30	
Maneuvering speed	0.07	0.09	0.27	90	
Maneuvering speed (big waves)	0.14	0.20	0.61	50	

The final results of the executed measurements and assessments of mechanical vibrations at the workstations on the tested inland waterway crafts are presented in Table 4.

Table 2: Results of the vibration measurements and assessments.

Object	Whole-body vibration		Hand-arm vibration		Vibration in relation to acceptable values	
	daily exposure $A(8)_{WB}$ [m/s^2]	multiplicity of exceeding the limit value 0.8 m/s^2	daily exposure $A(8)_{HA}$ [m/s^2]	multiplicity of exceeding the limit value 2.8 m/s^2	overall frequency-weighted r.m.s. vibration acceleration value a_w [m/s^2]	multiplicity of exceeding the acceptable value 0.179 m/s^2
Police boat	$A_Z(8)$ = 0.17	0.21	0.87	0.32	a_{wz} = 0.35	1.96
Rescue boat	$A_Z(8)$ = 0.08	0.10	0.09	0.03	a_{wz} = 0.08	0.45
Tourist vessel	$A_Z(8)$ = 0.03	0.04	0.09	0.03	a_{wz} = 0.04	0.22

5. Conclusions

The highest vibration acceleration values were recorded on the the police boat, which was moving at a significantly higher speed than the other tested inland waterway crafts. Based on the comparison of calculated exposure values to vibrations with permissible values, it can be concluded that:

- no exceedances of permissible values for whole-body vibrations occurred at any of the examined workstations,
- no exceedances of permissible values for hand-arm vibrations occurred at any of the examined workstations.

Analysing the obtained vibration acceleration values according to the ISO 20283-5:2016 standard, it can be observed that in the case of the police boat steersman, the measured values exceeded acceptable values almost by 2 times. In the remaining cases, no exceedances occurred.

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