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MULTIPLE PHYSICAL STRESS EXPOSURES OF SAILORS ON SEVERAL SHIPS - A LONGITUDINAL STUDY

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Abstract
Tthis paperdescribes how a series of stressors (temperature, humidity, noise, whole body vibration and hand-arm vibration) act on the discomfort of sailors, implicitly on the performance of their work. Until now, the effects of stress caused by various external factors on the working capacity of sailors have not been studied in detail. Experiments have been made on sailors (36 men) on several Danube vessels, two tugs, two push-tug boats and a push boat, during the day (max. 15 hours) and at night (max. 13 h), during summer (max. 32^0C outside) and winter (min. -10^0C outside). We made the following measurements: the temperature and humidity (weather station Kestrel 4000) in the wheelhouse, the sound level (01db Blue Solo sonometer) and the vibrations transmitted to the whole body (vibrometer Maestro 01 dB). The discomfort was determined using the Likert scale. The tests of human performances were analyzed with the Semmes-Weinstein test and the Purdue Pegboard test. In the wheelhouse we measured: temperature (max. 34^0C ÷ min. 5^0C), humidity (max. 87% - min. 54%), sound level (max. 96dB ÷ min. 84dB), whole body vibration (max. 7,4m/s^2 ÷ min. 2,7m/s^2) and hand-arm vibration (max. 6,2m/s^2 ÷ min. 2,3m/s^2) on all segments. Even if the subjects did not report any discomfort, tests have indicated that they have suffered a great discomfort. Following the determinations, it can be stated that there is a significant difference between the obtained results and the values indicated by the European Directives. Sailors work in very difficult conditions. There are many ways to decrease the sailors' discomfort, but they require special financial efforts that Romania has not yet made.

Keywords: Multi-stress, temperature, humidity, noise, whole-body vibration, hand arm vibration, discomfort, Likert scale, work performance

1. INTRODUCTION

At each workplace there are stressors that lead to lower productivity, for example: too high or too low temperature and humidity, vibrations transmitted to the human body, noises that exceed legal limits, etc. There are many studies that analyze these stressors [1-8].

There are countries that are investing a lot in transport comfort; for example "Canada's rail industry has invested more than $20 billion since 1999 to improve the safety of users as a top priority. Although the accident rates have decreased, the users' safety and comfort could still be impacted by vehicle's vibration, air quality, and noise levels. In this regard, comfort and safety are mutually related aspects; worsening of air quality could compromise users' safety from a respiratory health perspective. Further, noise, level of lighting, thermal condition and movement could contribute to hearing problems, visual impairments, bacteria growth, and nausea, respectively. Management of urban transit systems should ensure a convenient transit service with adequate levels of ride and quality (time and cost) as well as users' comfort and safety.”[9]

Another stress factor at the workplace is the temperature; in this regard, Ramsey et al. [10] examined the workers’ behavior in two industrial plants, for 14 months. It was found that lower or higher temperatures than normal values for most people, had a negative impact on the behavior regarding the workers’ safety meaning that there were several unsafe behaviors at the workplace.

Low back pain among mineworkers in relation to driving, cold environment and ergonomics was studied by Skandfer et al in 2014 [11]. They analyzed ”the association between low back pain (LBP) and exposure to low temperature, wet clothes, heavy lifting and jobs that involve whole body vibration (WBV) in a population of miners. Wet clothing, cold working conditions, heavy lifting, previous work as a driver and driving certain vehicles were associated with LBP, but vehicles with WBV levels above action value were not. For better prevention of LBP, improved cabin conditions and clothing should be emphasized”.

Noise at work is extremely disturbing. ”Noise, hearing loss, and electronic signal distortion, which are common problems in military environments, can impair speech intelligibility and thereby jeopardize mission success” [12] .

One of the professions where there are many problems and which requires increased attention from the workers is the sailor profession [13].

”The experiment shows noise presence as nuisance that affects sailors. Noise presents a serious threat for the sailors’ health” [14, 15].

And the vibrations transmitted by the moving parts of the ships induce a further fatigue of the sailors: ”this stress is continued after the working program, because the crew does not leave the ship. These vibrations can impair well - being, efficiency and the health of people on board; this leads to the muscle and bone system disorder of the hand, arm, neck and back and also can cause damage to the ship and its cargo, and can compromise the safety of the vessel” [16].

Unfortunately, the situation in Romania is more difficult; there was not enough money allocated for renewing the river park and improving transport on the Danube. For this reason, the ships are old and implicitly there are the stressors I mentioned above.

The purpose of this paper is to determine how a sailor reacts to an accumulation of high external stressors: temperature, humidity, noise and whole-body vibration.

2. EXPERIMENTAL

Experiments were made on sailors (36 men) from 5 ships on the Romanian segment of the Danube, as follows: a push boat (ship A), two tugs (cases B & C) and two push-tug boats (vessels D and E), during the day (max 5 h) and by night (max 3 h), during summer (max 42^{0}C outside) and winter (min -16^{0}C outside).

Table 1. Characteristics of the subjects

Total number	36 men
Age	44÷61 years
Seniority	23÷34 years
Smokers	28 (77.77%)
Sports active people	2 (5.55%)
Overweight (BMI ∈ 25÷30)	17 (47.22%)
Obese (BMI > 30)	1 (2.77 %)
Drink - less than 2 glasses of wine/day	11 (30.55%)
Drink - more than 2 glasses of wine/day	25 (69.44%)
Cardiovascular diseases	4 (11.11%)
Cardiovascular diseases in the family	12 (33.33%)
Declared personal problems	12 (33.33%)
Declared financial problems	31 (86.11%)

2.1. Participants

Each participant was asked to complete a health screening questionnaire to give written consent for tests and was instructed in writing concerning the experiment. Participants were informed that they may abandon the experiment at any time for any reason. The group is very heterogeneous both as physical features and as habits (Tab. 1.).

Table 2. Experimental conditions

Case	**Study area**	**Speed $\overline{v}$ (km/h)**	**Subjects**	**day/night**	**Total time t(h)**
A push boat	Braila Turnu Severin	~ 15	1-2	day	17 h
			3-4		
			5-6	night	19 h
			7-8		
B tug		~ 14	9-10	night	18.5 h
			11-12		
C tug	Turnu Severin Braila	~ 17	13-14	day	22.5 h
			15-16		
			17-18	night	22.5 h
			19-20		
D push-tug boat	Braila Turnu Magurele	~ 14	21-22	day	14 h
			23-24		
			25-26	night	16 h
			27-28		
E push-tug boat	Turnu Magurele Braila	~ 16	29-30	day	14.50 h
			31-32		
			33-34	night	12.50 h
			35-36		

2.2. Experimental conditions

Experimental conditions were shown in Tab. 2. Experiments were made between September 2016 and July 2017. The experiments consist of 2 parts:

<u>2.2.1. Measuring physical parameters:</u> In this paper we analyzed: temperature (T), humidity (u), sound level (L) and the vibrations transmitted to the whole body (acceleration a). The temperature and the humidity were measured with Kestrel 4000 Weather & Environmental Meter. The sound level was measured using a Blue Solo sound level meter. The vibrations transmitted were analyzed with vibrometer Maestro 01 dB using PCB Piezotronics 356A16 - Triaxial Accelerometers. The routes are in the southern parts of Romania; it is an approximately equal average of temperatures and humidities.

Table 3. Likert Scale

Degree of discomfort	**Scale**
Very strongly	4÷5
Strongly	3÷4
Slightly	2÷3
A little	1÷2
Not at all	0÷1

2.2.2. Tests of human performance: Subjects answered 2 types of tests: the first one refers to a subjective appraisal of the discomfort caused by stressors on subjects using the Likert scale; the second test measures the work performances of the subjects with: the Semmes-Weinstein test and the Purdue Pegboard test.

Discomfort determination using Likert scale: The first part of the tests of human performance was to determine the subjects' discomfort exposed to stressors, using the Likert scale (Tab. 3.). Each subject was given a score for what he felt after the experiment ended. The format of a typical five-level Likert item is shown in Tab. 3 [10]:

The Semmes-Weinstein test: a monofilament nylon wire exerts a 10 g force when stretched against the skin for 1 second. Patients who cannot feel this pressure on the surface of their legs are considered to have lost their tactile perception. The scale used is the Likert scale (1-5). We will do this test on the finger surface. The tests were repeated three times.

The Purdue Pegboard test: it is a test of manual dexterity. The Purdue Pegboard test uses a board with two parallel rows, each with 25 holes into which the subject places cylindrical metal nails. There is a short briefing at the beginning of the test. The subsets for preferred, non-preferred, and both hands require the subject to place the pins in the holes as quickly as possible and the score is the number of pins placed in 30 seconds. The tests were repeated three times [17].

3. RESULTS AND DISCUSSION

3.1. Temperature and humidity analysis inside the drivers compartments

The vast majority of vessels have air conditioning systems that do not work in normal conditions. However, deck work is difficult: the comfort index far exceeds (positive or negative) the optimal values required for a normal working climate. During summer, temperature and humidity are extremely high; in winter it is very cold for staff.

According to the "General Labour Protection Norms" of November 20, 2002 (Ministry of Labour and Social Solidarity), Art.3: work in command rooms, it is stated:

a) During summer:
- operating temperature between 23 - 26 °C;
- relative air humidity between 30-70%;

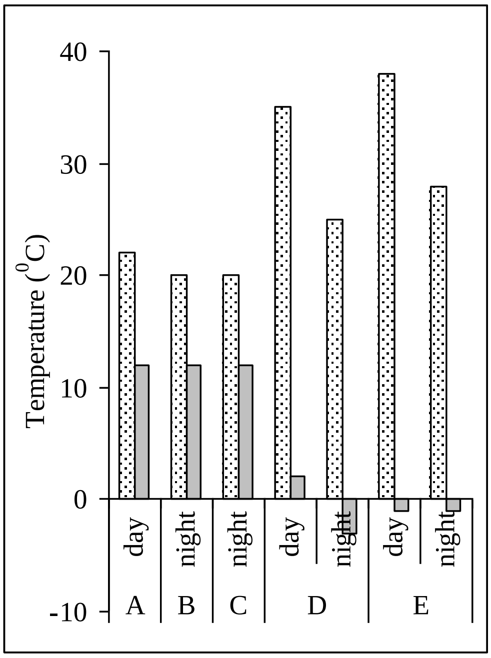

Fig. 1. Average temperatures recorded for each case ( ) - Summer average; ( ) - Winter average

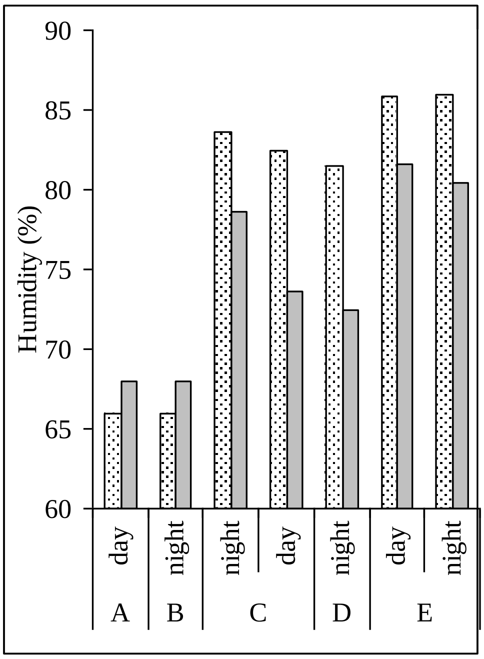

Fig. 2. Average humidities recorded for each case ( ) - Summer average; ( ) - Winter average

b) During the winter:
- operating temperature between 20 - 24 °C;
- relative air humidity between 30-70%;
- differences under 10°C between the radiation temperature of the windows or other vertical surfaces and the radiation temperature of the objects in the room [18].

For tugs (cases B and C), it is found that (Tab. 4.):
- the temperature is 20% higher in summer and 45% less in winter than the values stipulated by the law (Fig. 1).
- the humidity is 20% higher in summer and 11% less in winter than the values stipulated by the law (Fig. 2).

Table 4. Temperature and humidity conditions

Case	Moment of the day	Temperature		Humidity	
		July average	January average	July average	January average
A	day	22	24	40	45
B	night	20	12	66	68
C	night	20	12	83,6	78,6
D	day	35	2	82,5	73,6
	night	25	-3	81,5	72,4
E	day	30	0	85,9	81,6
	night	28	-1	86	80,4

It is also noticed that the worst working conditions are recorded in the case of D+E (push-tug boats), where exceedances record the most alarming rates.

For push boat A, which are equipped with air-conditioning systems, the working conditions respect the norms of normal conditions workplace.

3.2. Noise level analysis inside the drivers compartments

The worse condition of the ships in cases C, D and E is also reflected in the lack of sound insulation. Directive 2003/10 / EC provides that: ”a) exposure limit values are: $L_{EX,8h}$ = 87 dB(A) and p_{peak} = 200 Pa respectively; (b) upper exposure action values are: $L_{EX,8h}$ = 85 dB(A) and p_{peak} = 140 Pa respectively; (c) lower exposure action values: $L_{EX,8h}$ = 80 dB(A) and p_{peak} = 112 Pa respectively” [19].

Figure 3 shows that the sound level is exceeded 15% in the case of push-tug boat E; instead - for the cases B + C (tugs) - the sound levels are found around the triggering action (85 dB (A)). Only in the first cases – for the push boat, these levels are below 80 dB (A) - lower exposure values triggering the action.

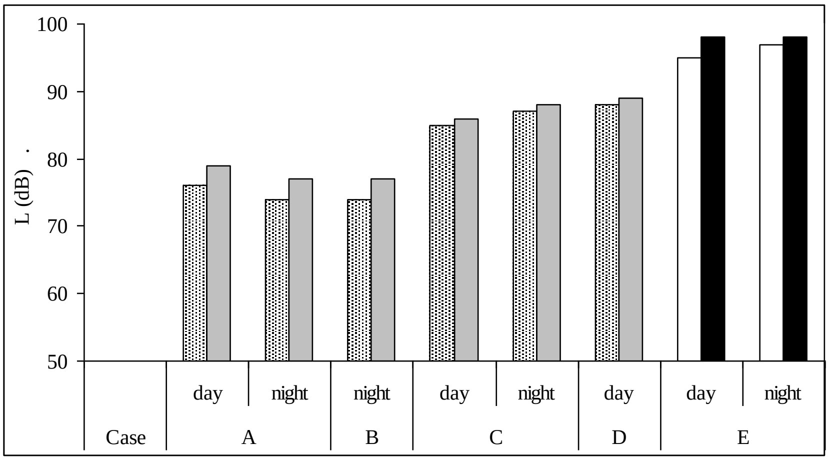

Fig. 3. Average sound levels recorded for each case (▒) - Summer average; (■) - Winter average; (□) - Summer average case E; (■) - Winter average for case E

3.3. WBV and HAV analysis inside the drivers compartments

Regarding the transmission of vibrations to the sailors' vessels, the same phenomenon arises: the vessels C, D and E (tugs and push-tug boats) generate dangerous vibrations for the staff in terms of whole body vibration (WBV) and hand-arm vibration (HAV). Directive 2002/44 / EC provides that:
1. For hand-arm vibration:
(a) the daily exposure limit value standardized to an eight-hour reference period shall be 5 m/s^2;
(b) the daily exposure action value standardized to an eight-hour reference period shall be 2,5 m/s^2.
2. For whole-body vibration:
(a) the daily exposure limit value standardized to an eight-hour reference period shall be 1,15 m/s^2 or, at the choice of the Member State concerned, a vibration dose value of 21 $m/s^{1,75}$;
(b) the daily exposure action value standardized to an eight-hour reference period shall be 0,5 m/s^2 or, at the choice of the Member State concerned, a vibration dose value of 9,1 $m/s^{1,75}$ [20].

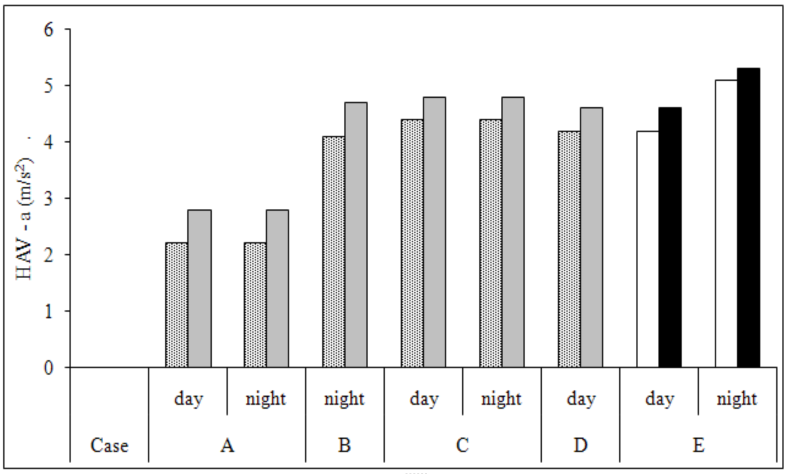

Fig. 4. Average HAV recorded for each case (▒) - Summer average; (▒) - Winter average; (□) - Summer average for case E; (■) - Winter average for case E

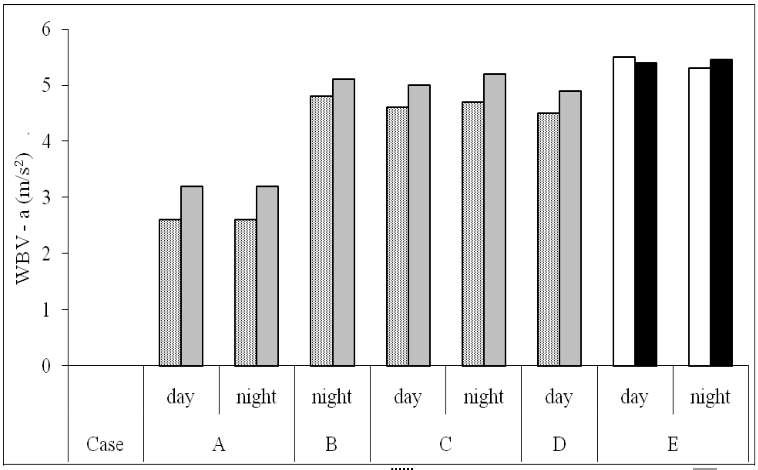

Fig. 5. Average WBV recorded for each case (▒) - Summer average; (▒) - Winter average; (□) - Summer average for case E; (■) - Winter average for case E

3.4. Tests of human performance

In the second part of the study, the subjects solved the Semmes-Weinstein test and the Purdue Pegboard test after a work shift [18]. The degree of discomfort was assessed using the Likert scale (Fig. 6÷9).

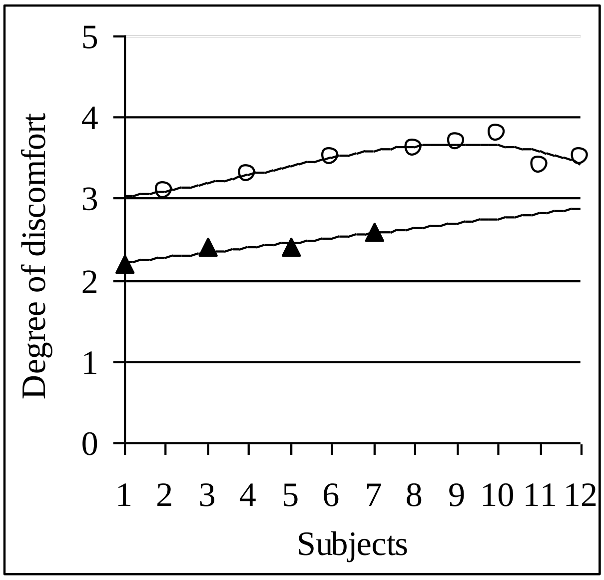

Fig. 6. Discomfort variation in the case of push boat (cases A+B)
(▲) - Subjects 1, 3, 5 and 6 declared "Slightly"; (○) - Subjects 2, 4, 6, 8, 9, 10, 11 and 12 declared "Strongly"

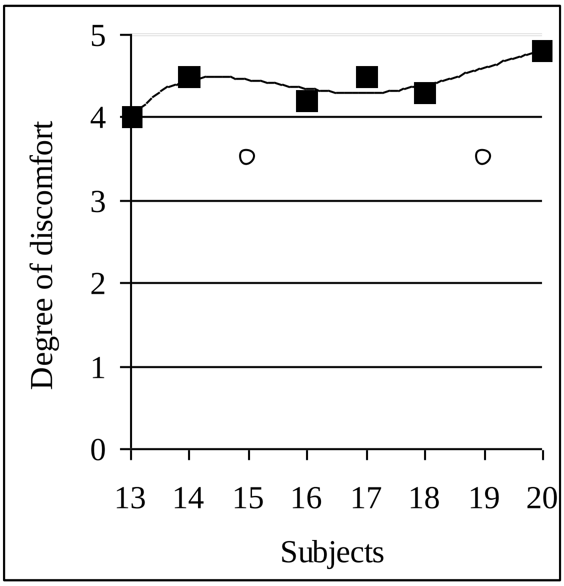

Fig. 7. Discomfort variation in the case of tug boats (case C)
(○) - Subjects 15 and 19 declared "Strongly"; (■) - Subjects 13, 14, 16, 17, 18 and 20 declared "Very strongly"

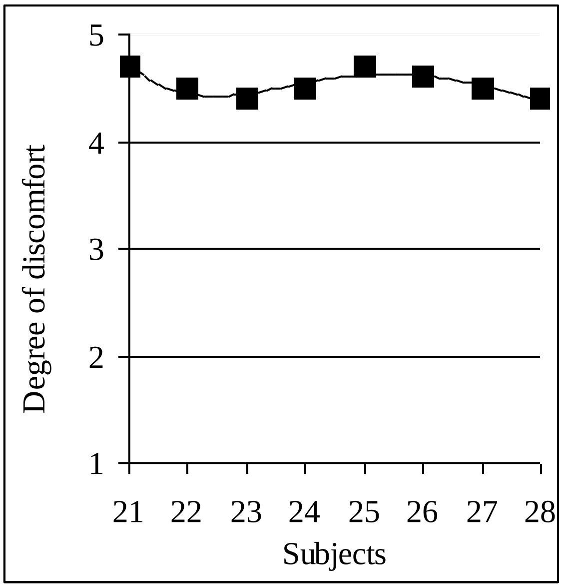

Fig. 8. Discomfort variation in the case of push-tug boats (case D)
(■) - All subjects (21 ÷ 28) declared "Very strongly"

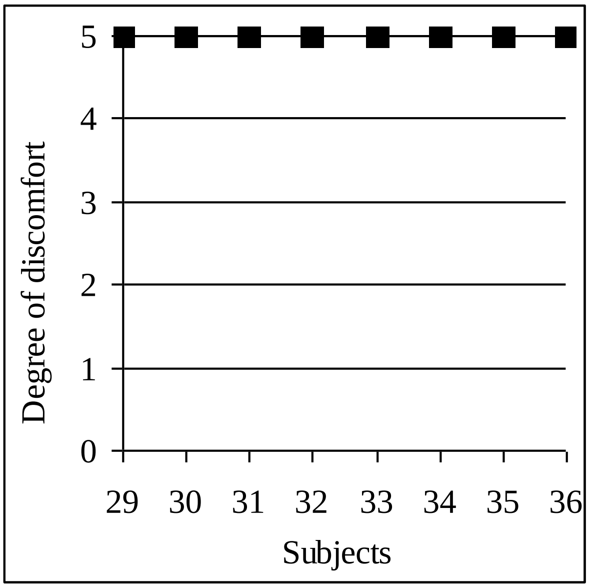

Fig. 9. Discomfort variation in the case of push-tug boats (case E)
(■) - All subjects (29 ÷ 36) declared "Very strong" with a maximum value 5.

Subjects were then tested also with the Semmes-Weinstein monofilament experiment. The experiments used only the regular monofilament of 10g, the one from which any verification begins. Monofilaments were applied on all fingers and testing was repeated three times (maximum 10 fingers x 3 = 30 touchings).

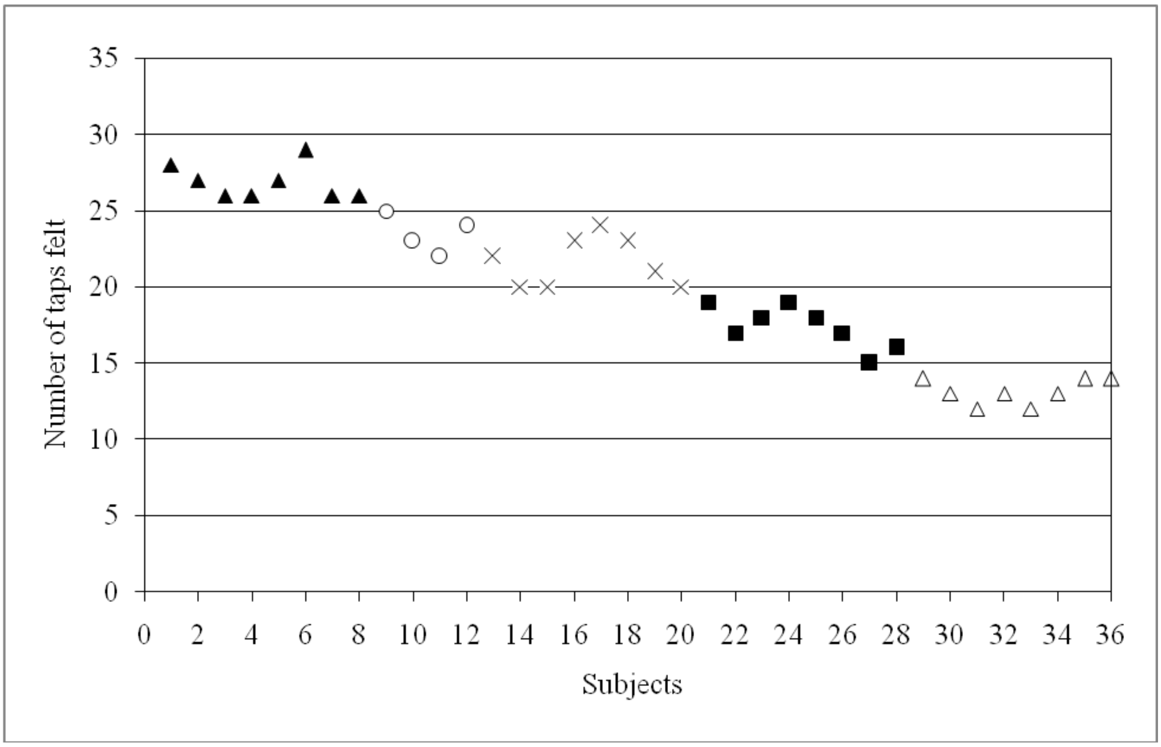

Fig. 10. Number of taps felt by each subject

The results confirm what these people said at the Likert test. It was noticed that the fingers of the subjects became much number when the vibration parameters increased.

The subjects also participated at the Purdue Pegboard test; they were asked to put 20 nails in holes in a maximum of 30s. This experiment took place before and after the work shift. The average results of the Purdue Pegboard test for subjects are shown in Fig. 10.

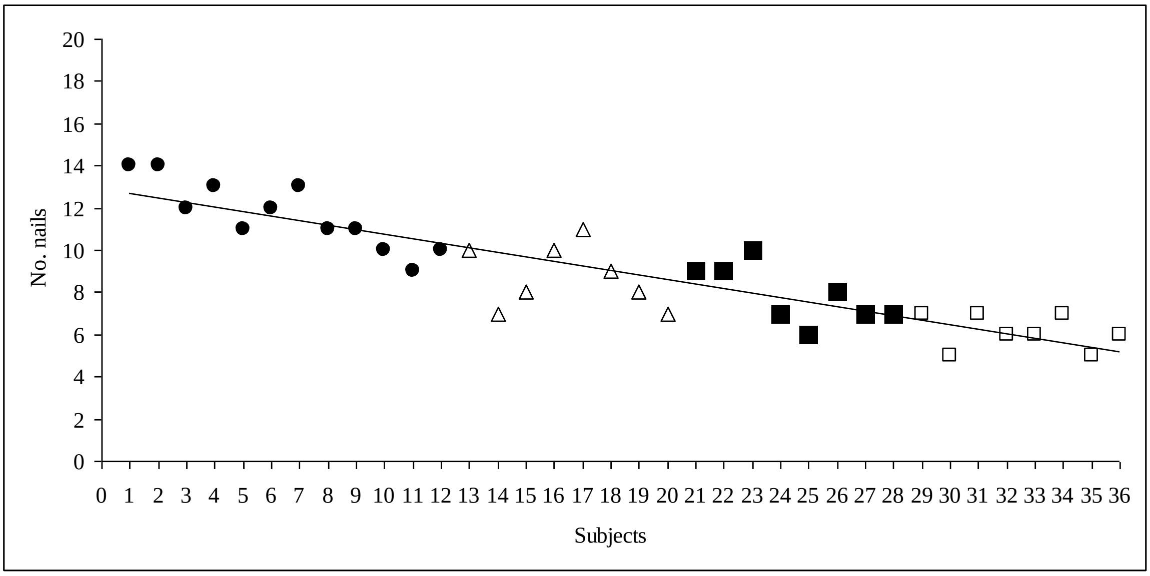

Fig. 11. Average of the results obtained for the Purdue Pegboard test
(●) – Cases A+B; (Δ) – Case C; (■) – Case D; (□) – Case E

Figure 11 shows that the maximum score (20 nails in the holes) was not achieved in any way. The best score is for the push boat sailors and it is worse for push-tug boat (case E) sailors.

4. CONCLUSIONS

Taking into account the analyzed ones, there is an urgent need to invest heavily in the renewal of all vessels equipment, because it is also old, it often breaks, endangering people's lives. Sailors work in harsh conditions and it was found that this had a direct impact on their productivity. The vassels must be equipped with modern air conditioning systems to ensure the temperature and humidity at the values indicated by the current rules.

The European rules on noise must also be respected, as follows (According to DIRECTIVE 2003/10/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 6 February 2003 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise), SECTION II, OBLIGATIONS OF EMPLOYERS, Article 5: Provisions aimed at avoiding or reducing exposure) [19]:

(a) taking into account the technical progress and the availability of measures to control the risk at source, the risks arising from exposure to noise shall be eliminated at their source or reduced to a minimum.

(b) the choice of appropriate work equipment, taking into account the work to be done, emitting the least possible noise, including the possibility of making available to workers work equipment subject to Community provisions with the aim or effect of limiting exposure to noise;

(c) the design and layout of workplaces and work stations;

(e) noise reduction by technical means: reducing airborne noise, e.g. by shields, enclosures, sound-absorbent coverings; reducing structure-borne noise, e.g. by damping or isolation;

(f) appropriate maintenance programmes for work equipment, the workplace and workplace systems;

The European rules must be respected also in terms of vibrations transmitted to the human body, as follows (According to DIRECTIVE 2002/44/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 June 2002 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration), SECTION II, Article 5, Provisions aimed at avoiding or reducing exposure) [20]:

(a) taking into account the technical progress and the availability of measures to control the risk at source, the risks arising from exposure to mechanical vibration shall be eliminated at their source or reduced to a minimum.

(b) the choice of appropriate work equipment of appropriate ergonomic design and, taking account of the work to be done, producing the least possible vibration;

(c) the provision of auxiliary equipment that reduces the risk of injuries caused by vibration, such as seats that effectively reduce the whole-body vibration and handles which reduce the vibration transmitted to the hand-arm system;

(d) appropriate maintenance programmes for work equipment, the workplace and workplace systems;

(g) limitation of the duration and intensity of the exposure;

(h) appropriate work schedules with adequate rest periods;

(i) the provision of clothing to protect exposed workers from cold and damp.

To sum up, great efforts are necessary to be made by all the responsible actors in order to replace the old vessels equipment with new ones thus the staff can work or travel in good conditions according to the European standards.

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