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AN ANALYSIS OF VIBRATION TRANSMISSION TO HANDLERS TRUCKS

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ABSTRACT

During movement of vehicles, drivers are subjected to vibrations transmitted by the engine, road irregularities, etc. They are extremely harmful for drivers and passengers.

In this paper were studied and measured the vibrations accelerations transmitted by the vehicle when: the driver sits directly on the car seat and the driver sits on ergonomic seat cushion, in two cases: driving on asphalt and on macadam. The accelerometers were fixed on the floor, on the seat, on the lumbar area, on the cervical area and on the forehead, at eight male subjects of different BMI and ages. For these cases, were calculated the root mean square average vibration, the vibration dose value, the time period needed to reach the value of the exposure which triggers the action and the limit exposure value and the seat effective amplitude transmissibility for A_w and VDV. It was found that in all cases, seat cushion decreased the transmission of vibration, so the travelling conditions are improved. In these cases, the following results were obtained: If the driving occurs on asphalt, the root mean square average vibration measured at the forehead decreased by 9.09% and on macadam, the decrease was of 8%. VDV decreased by 20.69% on asphalt and on macadam, the decrease was of 14.81%. T_{EAV} increased by 21% on asphalt and on macadam, the increase was of 18.12%. T_{ELV} increased by 21.05% on asphalt and on macadam, the increase was of 18.20%.

KEYWORDS: WBV, seat cushion, root mean square average vibration, dose-response, seat effective amplitude transmissibility

1. INTRODUCTION

Whole-body vibration is experienced in surface and air transport, with motion sickness its most familiar effect. A more serious as disorder, known as Raynaud's syndrome or vibration white finger (VWF), can result from the extensive use of vibratory hand tools, especially in cold weather. The condition is seen most frequently among workers who handle chain saws, grinders, pneumatic drills, hammers, and chisels. Forestry workers in cold climates are particularly at risk. Initial signs of VWF are tingling and numbness of the fingers, followed by intermittent blanching; redness and pain occur in the recovery stage. In a minority of cases, the tissues, bones, and joints affected by vibration may develop abnormalities; even gangrene. VWF can be prevented by using properly designed tools, avoiding prolonged use of vibrating tools, and keeping the hands warm in cold weather [2].

There are two types of occupational vibrations: of one segment and of the whole body. The vibrations from the steering wheel are transmitted through the hand and arm and lead to some specific disorders like Raynaud Syndrome (Fig. 1). The whole-body vibration is transmitted through the support surfaces of the body: legs, for the vertical position case, or buttocks and back, for the seated position [1].

Figure 1. Raynaud Syndrome

In medicine, Raynaud's phenomenon is a vasospastic disorder causing discoloration of the fingers, toes, and occasionally other areas. This condition may also cause nails to become brittle with longitudinal ridges. Named after French physician Maurice Raynaud (1834–1881), the

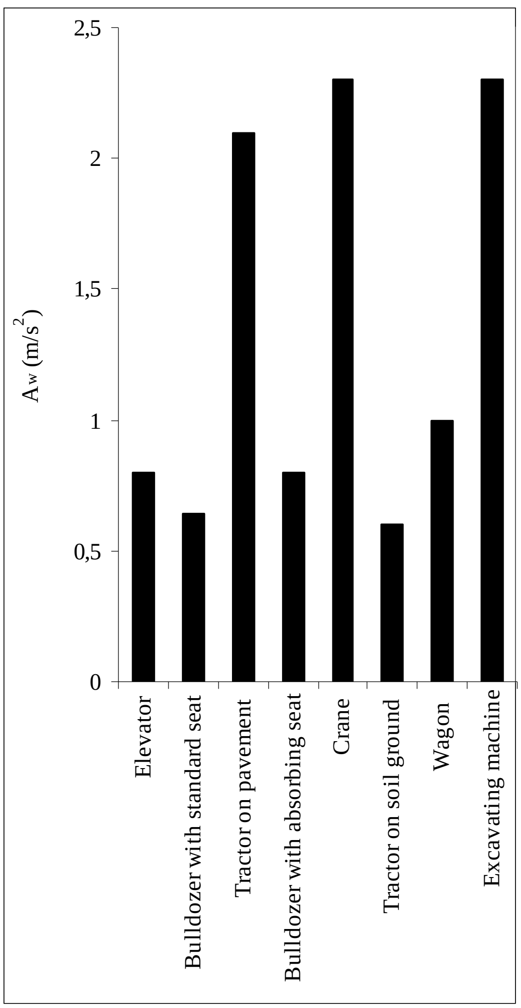

Figure 2. Vibration values for different vehicles

phenomenon is believed to be the result of vasospasms that decrease blood supply to the respective regions. Stress and cold are classic triggers of the phenomenon [4.].

If in contact with a vibrating vehicle, the energy of the vibration is transferred to the human body. Depending on the type of exposure, the vibrations can affect an important part of the workers' body or only a certain body-part. The effects of exposure to vibrations are also influenced by their frequency. Each organ has its own resonance frequency. If the exposure happens at that resonance, or at a close frequency, the result is emphatic [3].

The energy of the whole-body vibration is transmitted to the body through the floor or chair and affects the whole body or a lot of body-parts. The exposed groups include truck drivers, bus drivers, tractor drivers but also the ones who work on vibrating surfaces [9].

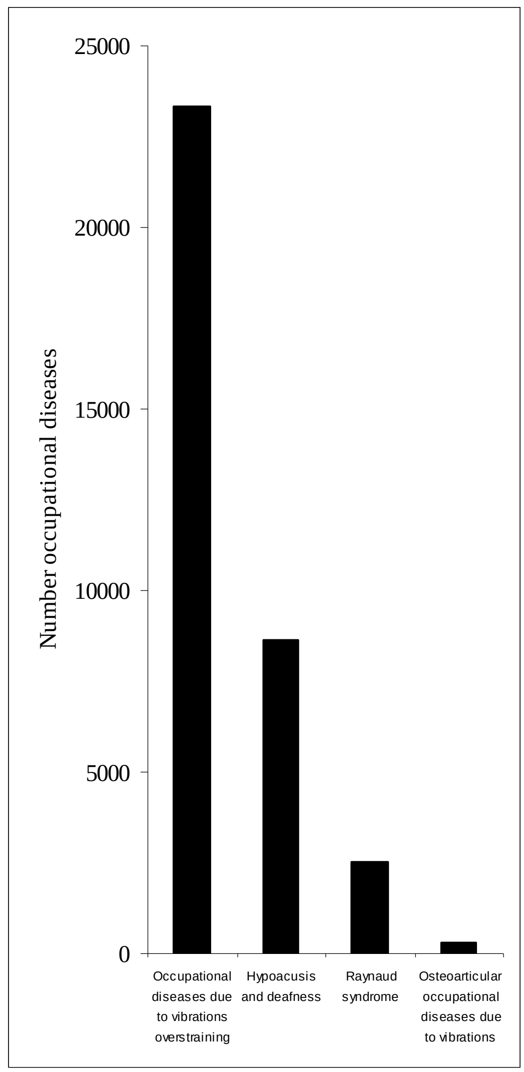

Figure 3. Total occupational diseases due to physical agents (noise and vibrations) 2000-2010

Short term exposure to vibrations in the range of 2-20Hz, at $1m/s^2$, leads to the following symptoms [5]: heavy feeling in head, headache, dizziness, irritability, difficulty in falling asleep, loss of appetite, weak stomach, palpitation, arm dullness, stiff shoulder, dullness in lower limbs, morning stiffness in fingers, finger tremor, low back pain, numbness in finger, Raynaud's phenomenon in fingers, impairment of visual acuity, impairment of hearing acuity [6]. Long term exposure to vibrations can lead to serious health problems, especially to the backbone**,** degenerative changes in the spine, disc hernia, lumbar scoliosis, intervertebral disk diseases, digestive system diseases, urogenital disorders [8].

Because of the difficult evaluation of the response to vibrations and of the inconsistency of the data obtained after research, ISO 2631-1:1997, ISO 2631-4:2001 established "The Evaluation of the Human Exposure to Whole- Body Vibrations".

Many studies published the levels of vibrations for different vehicles used in civil engineering, agriculture and industry. The vibrations values were measured on different types of terrain with vehicles of different fabrication years, etc (Fig. 2).

Between 1997 and 2010, in Romania, the occupational diseases due to osteomuscular overstraining are on the top positions, followed by occupational diseases due to noise, cutaneous diseases, Raynaud syndrome, etc. [12] (Fig. 3).

2. MATERIALS AND METHODS

To determine the way in which the vibrations transmitted by the vehicle influence the drivers' bodies, were determined the vibrations accelerations transmitted by the vehicle to the driver. The vibrations will be measured in 2 cases: the driver sits directly on the car seat and the driver sits on ergonomic seat cushion, both at driving on asphalt and on macadam. Also were determined the vibrations accelerations transmitted by the vehicle to the driver. The vibrations will be measured in 5 cases: the accelerometer is fixed on the floor, the accelerometer is fixed on the seat, on the lumbar area, on the cervical area and on the forehead. The measurement time for every test set was 10 minutes [7].

The vibrations were measured in normal working conditions, according to International Standard ISO 2631-1. The whole body vibration, in different conditions, was measured on the 3 axes x, y and z from the centre of the human body. The whole body vibrations were measured using: 01dB NetdB Multichannel digital recorders and real-time analysers with 12 activated channels acquisition, triaxial whole-body accelerometer SEAT-pad (Seat Effective Acceleration Transmissibility) mounted on the driver's floor, seat and lumbar and triaxial whole-body accelerometer PCB Piezotronics 356A16 mounted on the driver's cervical area and forehead. The accelerometer was fixed with clips on the steering wheel, according to ISO 5349-2:2001 [13]. The axes were oriented in the directions specified in EN 1032:2003 [14]. The accelerations generated by vibrations were calculated using the weight factors set by ISO 2631. The calibration of the accelerometers was made with VE-10 Rion.

The data processing was made with dBFA Suite–Control Software for data acquisition and post-processing. The data acquired during the experiments were processed using the calculation given by ISO 2631-1-1997. Comparisons were made between seats, road types and accelerometer positions. The ISO 2631-1 parameters evaluated included:

a) Root mean square average vibration (Aw) calculated at the floor, seat, lumbar, cervical and forehead:

$$A_w = \left[\frac{1}{T} \int_0^T a_w^2(t)dt \right]^{1/2} \quad (m/s^2) \qquad (1)$$

b) Vibration dose value (VDV). This value is more sensitive to impulsive vibration and reflects the total, as opposed to average vibration:

$$VDV = \left[\frac{1}{T} \int_0^T [a_w(t)]^4 dt \right]^{1/4} \quad (m/s^{1.75}) \qquad (2)$$

c) The time period needed to reach the value of the exposure which triggers the action (EAV) and the limit exposure value (ELV):

$$T_{EAV_{A(8)}} = 8\left(\frac{0,5}{A_w}\right)^2 \quad (h) \qquad (3)$$

$$T_{ELV_{A(8)}} = 8\left(\frac{1,15}{A_w}\right)^2 \quad (h) \qquad (4)$$

d) Seat effective amplitude transmissibility (SEAT) (for Aw and VDV) provides a measure of how well a seat is suited to the spectrum of vibration entering the seat:

$$SEAT\ A_w = \frac{A_{w_{seat}}}{A_{w_{floor}}} \times 100\ (\%) \qquad (5)$$

$$\text{SEAT VDV} = \frac{VDV_{seat}}{VDV_{floor}} \text{ x } 100\ (\%) \qquad (6)$$

3. RESULTS AND DISCUSSION

The following figures present the results of measurements.

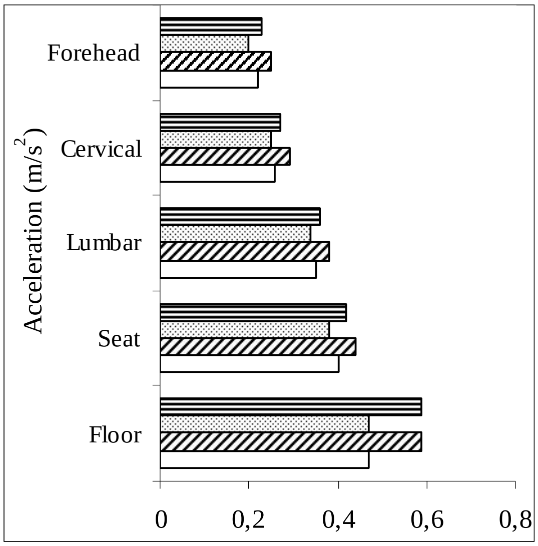

Figure 4. Root mean square average vibration, calculated at the floor, seat, lumbar area, cervical area and forehead, when driving on asphalt and macadam, without cushion and with ergonomic seat cushion (□) - without cushion, asphalt; (///) - without cushion, macadam; (▒) - ergonomic seat cushion, asphalt; (≡) - ergonomic seat cushion, macadam

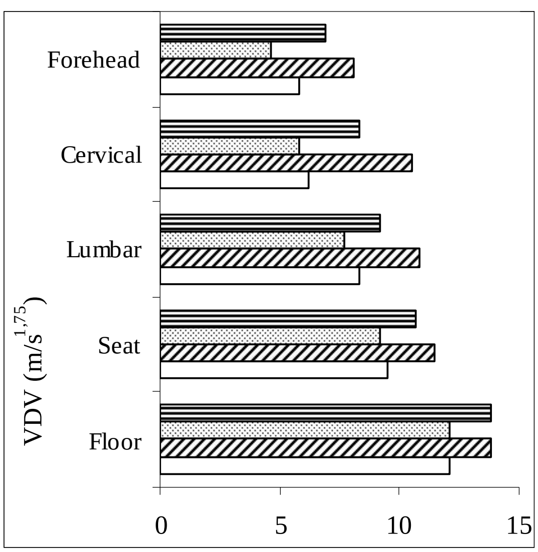

Figure 5. Vibration dose value, calculated at the floor, seat, lumbar area, cervical area and forehead, when driving on asphalt, macadam and ground, in 3 cases: without cushion and with ergonomic seat cushion (□) - without cushion, asphalt; (///) - without cushion, macadam; (▒) - ergonomic seat cushion, asphalt; (≡) - ergonomic seat cushion, macadam

Figure 4 shows that at the floor level, Aw M (AwM) is 1,53 times higher than Aw asphalt (Awa). It is clear the influence of the road type on which the car is rolling. If the driver does not use the seat cushion, AwM is 1,14 (lumbar)÷1,46 (cervical) times higher than AwA in the same conditions. If the driver does use the seat cushion: AwM is 1,03 (ergonomic) times higher than AwA (lumbar), respectively Awm is 1,44 (ergonomic) times higher than AwA in the same conditions.

Figure 5 shows that at the floor level, vibration dose value in the case of running on macadam (VDVM) is 1,42 times higher than vibration dose value in the case of running on asphalt (VDVA). It is clear the influence of the road type on which the car is rolling. If the driver does not use the seat cushion, VDVM is 1,41 (seat) ÷2,08 (forehead) times higher than VDVA in the same conditions. If the driver does use the seat cushion: VDVM is 1,42 (ergonomic) times higher than VDVA (seat), respectively VDVM is 2,1 (ergonomic) times higher than VDVA in the same conditions.

Figure 6 shows that at the floor level, TEAV in the case running on asphalt (TEAV-A) is 2,35 times higher than TEAV in the case of running on macadam (TEAV-M). It is clear the influence of the road type on which the car is rolling. If the driver does not use the seat cushion, TEAV-A is 1,86 (seat) ÷2,13 (cervical)

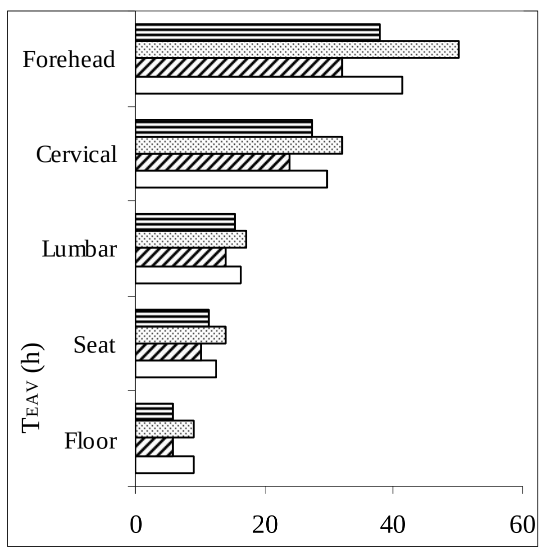

Figure 6. Time periods to reach the exposure value which triggers the action, calculated at the floor, seat, lumbar area, cervical area and forehead, when driving on asphalt, macadam and ground, in all 3 cases: without cushion and with ergonomic seat cushion (□) - without cushion, asphalt; (///) - without cushion,

macadam; (▒)ergonomic seat cushion, asphalt; (≡) - ergonomic seat cushion, macadam

times higher than TEAV-M in the same conditions. If the driver does use the seat cushion, TEAV-A is 1,06 (ergonomic) times higher than TEAV-M (lumbar), respectively TEAV-A is 2,07 (ergonomic) times higher than TEAV-M (cervical), in the same conditions.

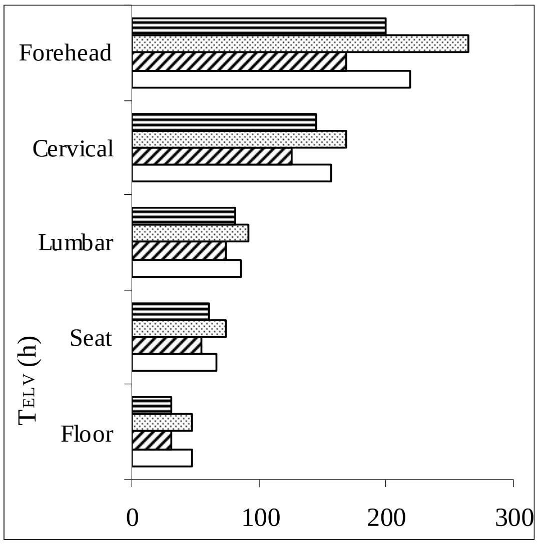

Figure 7. Time periods to reach the limit exposure value, calculated at the floor, seat, lumbar area, cervical area and forehead, when driving on asphalt, macadam and ground, in all 3 cases: without cushion and with ergonomic seat cushion (□) - without cushion, asphalt; (///) - without cushion, macadam; (▒) - ergonomic seat cushion, asphalt; (≡) - ergonomic seat cushion, macadam

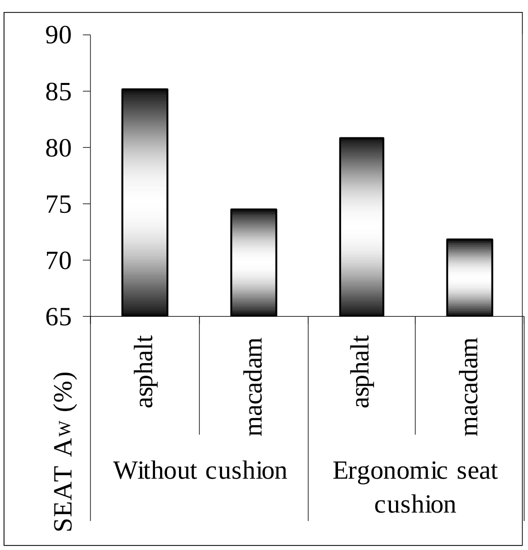

Figure 8. Seat effective amplitude transmissibility for Aw, calculated at the floor and seat, when driving on asphalt and macadam: without cushion and with ergonomic seat cushion

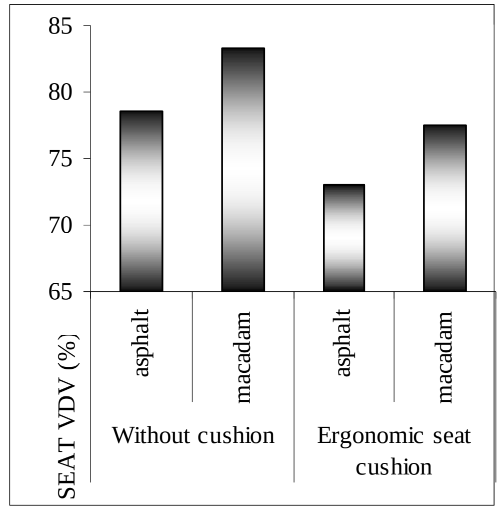

Figure 9. Seat effective amplitude transmissibility for VDV, calculated at the floor and seat, when driving on asphalt and macadam: without cushion and with ergonomic seat cushion

Figure 7 shows that at the floor level, TELV in the case of running on asphalt (TELV-A) is 2,34 times higher than TEAV in the case of running on macadam (TELV-M). It is clear the influence of the road type on which the car is rolling. If the driver does not use the seat cushion, TELV-A is 1,3 (lumbar) ÷ 2,13 (cervical) times higher than TELV-M, in the same conditions. If the driver does use the seat cushion, TELV-A is 1,06 (ergonomic), times higher than TELV-M (lumbar), respectively TELV-A is 2,07 (ergonomic) times higher than TELV-M (cervical), in the same conditions.

Figure 8 shows that if the driver does not use the seat cushion, SEAT AwM is 1.11 times lower than SEAT AwA and if the driver does use the seat cushion, SEAT AwM is 1.21 (ergonomic) times lower SEAT AwA.

Figure 9 shows that if the driver does not use the seat cushion, SEAT VDVM şi SEAT VDVA are aproximately equal. If the driver does use the seat cushion, SEAT VDVM si SEAT VDVA are aproximately equal.

4. CONCLUSIONS

In order to see how the vibrations are transmitted to the driver, it was made the parallel between seat effective amplitude transmissi-bility for Aw (SEAT Aw), calculated for rolling on asphalt and macadam in 2 cases: without cushion and with ergonomic seat cushion and also the parallel between seat effective amplitude transmissibility for VDV (SEAT VDV), calculated for rolling on asphalt and macadam in 2 cases: without cushion and with ergonomic seat cushion.

In conclusion, international organizations took measures against the negative effects of vibration, as follows: The Safety, Health and Welfare at Work (General Application) Regulations 2007, revoke and replace the Safety, Health and Welfare at Work (Control of Vibration) Regulations 2006. Part 5, Chapter 2 of the 2007 Regulations specifically addresses Control of Vibration at Work.

The regulations include requirements for an employer to:

a. Assess the vibration risk of their employees;
b. Decide if they are exposed above the daily exposure limit value (ELV); and if so, take immediate action to reduce their exposure below the ELV;
c. Decide if they are exposed above the daily exposure action value (EAV) and if so - introduce a programme of controls to eliminate or reduce their daily exposure so far as it is reasonably practicable;
d. Provide appropriate health surveillance to employees who continue to be exposed above the EAV;
e. Provide information and training to employees on health risks and controls to employees at risk;
f. Keep a record of their risk assessment and control actions;
g. Review and update their risk assessment regularly.

References

1. **Bovenzi M.** *A longitudinal study of low back pain and daily vibration exposure in professional drivers*. Ind Health. 2010; 48(5):584-95.
2. **Lundström R. şi Holmlund P.,** *Absorption of energy during whole-body vibration exposure,* Journal of Sound and Vibration, 215: 801-812, 2007.
3. **Mansfield, N.J., Holmlund, P., Lundström, R., Lenzuni, P. and Nataletti, P.,** *Effect of vibration magnitude, vibration spectrum and muscle tension on apparent mass and cross axis transfer functions during whole-body vibration exposure*, Journal of Biomechanics, Volume 39, Issue 16, Pages 3062-3070, 2006.
4. **M-Pranesh A, Rakheja S, Demont R.**, *Influence of support conditions on vertical whole-body vibration of the seated human body.* Industrial Health. 2010; 48(5):682-97.
5. **Matsumoto, Y. şi Griffin, M.J.,** *Nonlinear subjective and biodynamic responses to continuous and transient whole-body vibration in the vertical direction*, Journal of Sound and Vibration, Vol. 287, Issue 4-5, 4 pp 919-937, 2005.
6. **Nawayseh, N. and** Griffin M.J., *Effect of seat surface angle on forces at the seat surface during whole-body vertical vibration,* Journal of Sound and Vibration, 284:613-634, 2005.
7. **Picu, M., Nastac, S.,** *A study concerning the driver confort improvement as regards the transmited vibrations by the vehicle running on roads in Romania,* Carpathian Journal of Earth and Environmental Sciences, 2011, Vol. 6, No. 2.
8. **Seidel, H.,** *Selected health risks caused by Long-Term, Whole-Body Vibration,* American Journal of Industrial Medicine, 23, 589-604, 2003.
9. **Wijaya, A.R., Jönsson, P. and Johansson, O.,** *The effect of seat design on vibration comfort,* Int J Occup Saf Ergon, Volume 9, pp. 193-210, 2003
10. **ISO 2631-1:1997** – *Mechanical vibration and shock. Evaluation of human exposure to whole-body vibration*, Part 1: General requirements
11. **ISO 2631-4:2001** – *Mechanical vibration and shock. Evaluation of human exposure to whole-body vibration*, Part 4: Guidelines for the evaluation of the effects of vibration and rotational motion on passenger and crew comfort in fixed-guideway transport systems.
12. ***, Institutul naţional de statistica bolilor profesionale în România, http://www.protectiamuncii.ro
13. **ISO 5349-2:2001** *Mechanical vibration - Measurement and evaluation of human exposure to hand-transmitted vibration* -- Part 2: Practical guidance for measurement at the workplace
14. **EN 1032:2003** *Mechanical vibration. Testing of mobile machinery in order to determine the vibration emission* value.