AN INVESTIGATION ON THE HUMAN SENSATION INDUCED BY WHEEL HAND ARM VIBRATION AND SEAT WHOLE-BODY VIBRATION USING SINGLE AXIS AND TRIAXIAL METHODS – A STUDY USING THE STEVEN'S POWER LAW

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Abstract: The objectives of this study were to evaluate wheel hand arm vibration and seat whole-body vibration for different buses on different routes to determine the effect of pavement. Bus drivers are exposed to these vibrations during their work for 8 h/day. This leads to a muscular and bone system disorder of the hand, arm, neck and back. In our country was not made a close study regarding the connection between the hand arm and whole body vibrations and the occurrence of occupational diseases due to vibrations. In this paper 10 different types of buses were analyzed, with 10 drivers of 25-58 years of age. The routes covered by these buses were inside but also outside the city. The roads were of different qualities (asphalt, macadam and pavement). Also, the effects of higher speed on vibration were investigated. The combined effect of vibration magnitude and frequency on discomfort has been found to agree approximately with Stevens' Power Law. The growth in sensation (ψ) with increasing vibration magnitude (φ) has been studied on different city buses.

1 Introduction

Urban traffic drivers are exposed during their work hours to whole body and hard arm mechanic vibrations and some of them suffer from lumbar pain because of their work [2], [5]. To prevent the occurrence of some diseases in the case of professional drivers, due to vibrations, a study of oscillation motion is needed to make a connection between the body induced vibrations and the occupational diseases associated to vibrations [6]. In our country was not made until this date a study which regards the vibrations due to busses and minibuses. The purpose of this study is to measure the whole body and hand arm vibrations for drivers, during their work time, knowing that they are exposed for the entire work schedule, as opposed to fares who are exposed only occasionally [1] and the humans perceive vibrations induces by a running vehicle, starting from the Stevens' Power Law.

2 Equipments and method

In order to characterize the vibrations produced by different types of busses and minibuses measurements were made on 10 vehicles. To obtain information which covers a great variety of regnant intensities, frequencies and directions, 5 different routes were monitored (3 in the city and 2 outside the city, on asphalt, macadam and pavement). The velocity during the tests was normal for a working day. At this study, participated 10 medium built drivers of 28-54 years of age. The measurement time for every test set was 15 minutes.

The vibrations were measured in normal working conditions, according to International Standard. The hand-arm vibrations and the whole body vibration, in different conditions, were measured using a MAESTRO vibrometer, with a monoaxial and a triaxial accelerometer produced by 01dB-Metravib. The accelerations generated by vibrations were calculated using the weight factors set by ISO 5341-2 [8] and ISO 2631-1 [7].

The combined effect of vibration magnitude and frequency on discomfort has been found to agree approximately with Stevens' Power Law. The growth in sensation (ψ) with increasing vibration magnitude (φ) has been studied on different city buses.

3 Results and discussions

The composed motion on the 3 axes is higher then every component taken aside and over some limits can influence the driver. Every root-mean-square of the vibration accelerations at the driver seat interface (x-, y- and z-axes) is used to get relevant information – the root-mean-square of the total global acceleration, AWT:

$$A_{WT} = [(1.4a_x)^2 + (1.4a_y)^2 + (1.4a_z)^2]^{1/2} \quad (1)$$

The 1.4 factor is the ratio of the longitudinal and transversal curves values, of equal answer in human answers, the most sensible. The root-mean-square values for the weighted acceleration in frequency can be compared, for periods of 4–8h, to the pointed area from figure B.1, ISO 2631-1:2001, at the scheduled daily exposure period. Figures 1, 2, 3 and 4 present the measured values of the root-mean-square of the acceleration, generated by vibrations, weighted in frequency, for different work conditions, at the driver wheel and the driver’s seat interface, according to ISO 5341/2 and ISO 2631/1. The peak factor obtained during measurements did not exceed the value 9.

In this study, global r.m.s. acceleration data were compared to the bottom limit of the area in figure B.1, ISO 2631-1:2001, the one which was calculated with the B1 equation, from the standard.

For a more thorough articulation, the daily vibrations exposure dose eVDV is used, which is given by:

$$eVDV = 1.4 \cdot A_{WT} \cdot T^{1/4} \quad (2)$$

where T is the daily exposure to vibrations.

The daily vibrations exposure dose eVDV is between 8.5ms-1.75 and 17ms-1.75.

The result was that for majority of the studied cases the drivers can not work more than 8 hours a day, in safe conditions.

Table 1. The daily vibrations exposure dose for minimum and maximum accelerations

Acceleration dependence on	A_{WT} min (m/s^2)	A_{WT} max (m/s^2)	e_{VDV} ($ms^{-1.75}$) min	e_{VDV} ($ms^{-1.75}$) max
road type – hand arm measurement	1.13	2.10	20.57	38.24
speed – hand arm measurement	0.51	1.72	**9.28**	31.32
road type – whole body measurement	0.67	2.53	**12.2**	46.07
speed – whole body measurement	0.24	1.25	**4.37**	22.76

As it can be seen in Table 1, the ISO 5341/2 and ISO 2631/1 accepted values for the daily vibrations exposure dose are between 4.37 ms-1.75 and 12.2 ms-1.75, the rest far exceeding the legal values, therefore causing discomfort.

It is evident that the drivers from the urban public transport are exposed to higher and harmful values of vibrations. So, the purchase of newer and modern vehicles should be taken into account and also a new working schedule for the drivers should be introduce, in order to allow more resting time.

In this paper we will also refer to the way humans perceive vibrations induces by a running vehicle, starting from the Stevens’ Power Law [4]. This phenomenon takes into account two aspects: the perception magnitude and the comfort. The measurable physical magnitude was the acceleration transmitted to the hand-arm system.

The relationship is known as Stevens’ Power Law and is given by:

$$\psi = k\varphi^{\beta} \quad (3)$$

where ψ is the perceived magnitude, k is a scaling constant, φ is the physical magnitude and β is the stimulus dependent exponent.

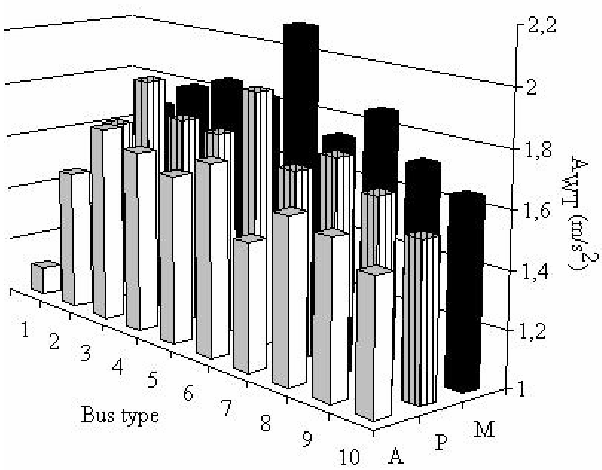

Figure 1. Acceleration dependence on road type (asphalt, macadam and pavement) – hand arm measurement

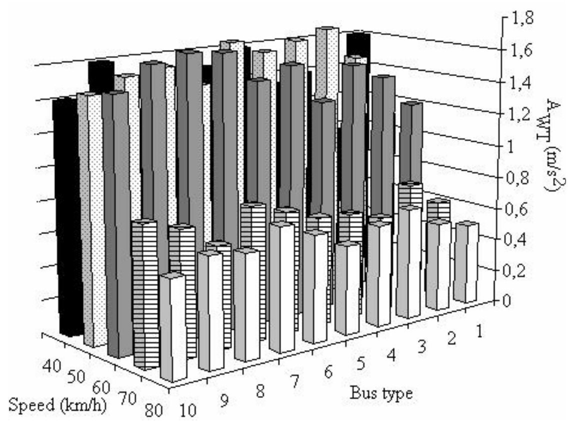

Figure 2. Acceleration dependence on speed – hand arm measurement

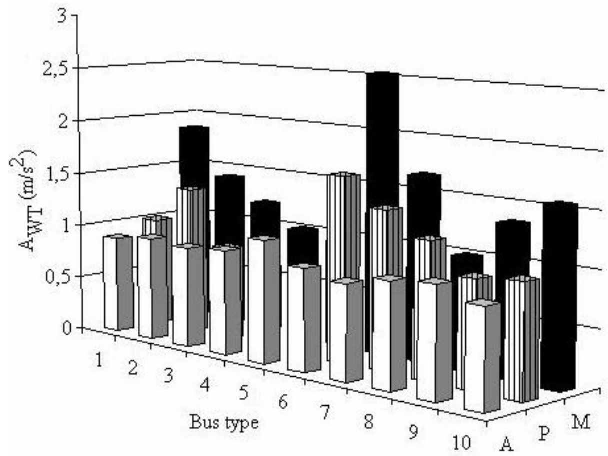

Figure 3. Acceleration dependence on road type (asphalt, macadam and pavement) – whole body measurement

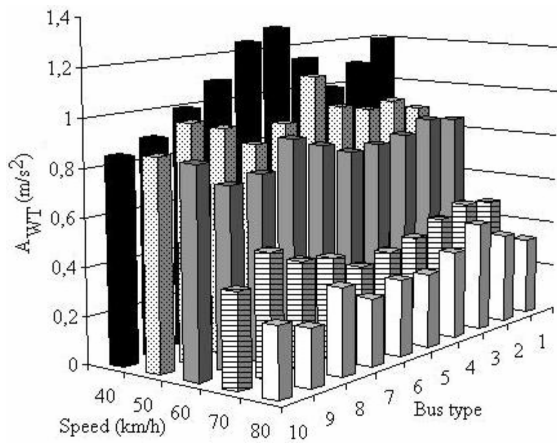

Figure 4. Acceleration dependence on speed – whole body measurement

The hand-arm vibrations were studied on a group of 6 drivers, of approximately same driving experience, same age (30-35 years old) and same body weight (80-90 kg). They drove the same vehicle and followed the same route for the same time period, trying in this way to obtain almost similar experiments. The acceleration measurements were made by mounting the triaxial accelerometers [3].

The r.m.s accelerations measured were 0,5m/s2, 0,8m/s2, 1m/s2, 1.5m/s2, 2m/s2 and respectively 2.2m/s2 at the frequency: 31Hz, 63Hz, 125Hz, 250Hz, 500Hz, 1000Hz, 2000Hz, 4000 and 8000Hz. The sensation magnitude was represented in Figure 5.

From figure 5 it can be seen that the shape of the curve corresponding to a given accele-ration magnitude varies with frequency, and that the effect of frequency decreases as the acceleration magnitude increases. The conceptual model presented included an increase in discomfort with vibration magnitude as well as an increase in discomfort with duration of exposure.

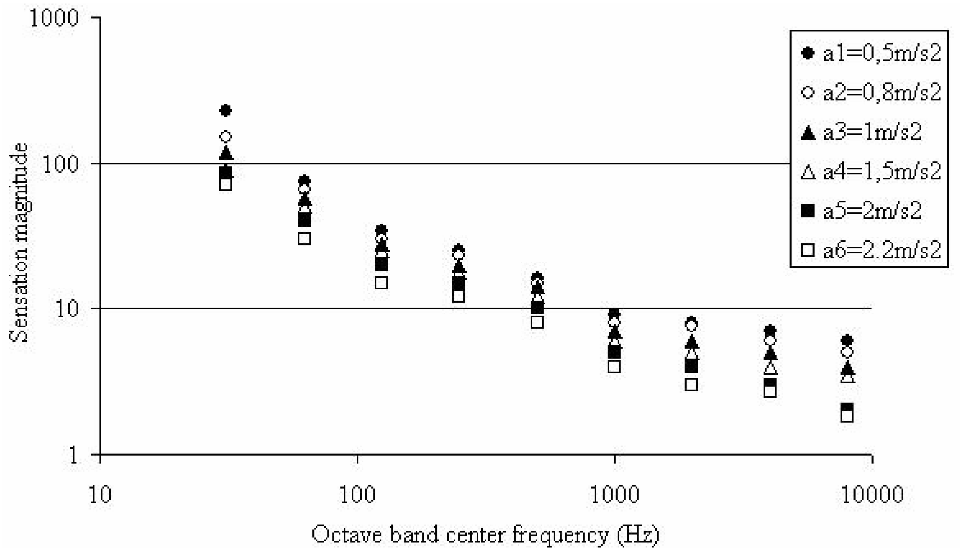

Figure 5. Stevens' Power Law – hand arm measurement

4 Conclusions

This study was made to evaluate the risks from driving urban traffic vehicles and it was noticed that: a) The estimated vibrations dose exceeds the minimum value of $eVDV=8.5m/s^{-1.75}$ in most of the studied cases. Even if the conventional work program is of 7 hours a day it is clear that the drivers should not be let to work those 7 hours in the current vibrations conditions; b) Regarding the humans perceive vibrations induces by a running vehicle, it can be seen that the discomfort increases with the increase of the vibration magnitude and with the duration of exposure.

References

[1] Griffin, M. J. (2000): Vibration and human responses, In Handbook of Human Vibration, London: Academic Press Inc.

[2] Hulshof, C., van Zanten, B.V (1997): Whole body vibration and low back pain, Intern. Archives of Occupational & Environmental Health, 59(3), 205–220.

[3] Mansfield, N.J. (2004): Human response to vibration, Technology & Engineering, CRC Press, Boca Raton. ISBN 0-415-28239-X.

[4] Stevens, S.S. (1957): On the psychophysical law, Psychological Review 64(3):153–181.

[5] Wilder, DG (2003): The Biomechanics of Vibration and Low Back Pain, American Journal of industrial Medicine. John Wiley & Sons, Inc. 23(4), 577–588.

[6] Wilkstrom, B., Kjellberg, A., Landstrom, U. (2004): Health effects of long-term occupational exposure to whole-body vibration: A Review. International Journal of Industrial Ergonomics, 14, 273–292.

[7] SR ISO 2631-1:2001 Mechanical vibration and shock, Evaluation of human exposure-part 1

[8] SR EN ISO 5341-2:2003 Mechanical vibration-Measurement and evaluation of human exposure to hand-transmitted vibration-part 2.