INFLUENCE OF VIBRATIONS AND DYNAMIC CHARACTERIZATION OF THE HUMAN BODY GENERATED BY CARS

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Rezumat. *Vibrațiile influențează corpul uman în diferite moduri. Răspunsul la o expunere a unei vibrații depinde în primul rând de frecvența, amplitudinea și durata ei. În această lucrare se studiază influența vibrațiilor generate de automobil asupra corpului uman, ținând cont atât de amplitudini cât, mai ales, de frecvențele acestor vibrații. Măsurarea acestor vibrații s-a făcut prin intermediul echipamentelor de ultima generație cu achiziția semnalelor de tip tridimensional.*

Abstract. *Vibrations influence the human body in many different ways. The response to a vibration exposure is primarily dependent on the frequency, amplitude, and duration of exposure. This paper studies the influence of vibrations generated by automobiles on the human body, taking into account both amplitude and especially the frequency of these vibrations. Measurement of these vibrations was made through the acquisition of latest equipment by acquiring tridimensional signals.*

Keywords: vibrations, triaxial accelerometer, frequency, acceleration, car

1. Introduction

The human body is both physically and biologically a "system" of an extremely complex nature. When looked upon as a mechanical system it can be considered to contain a number of linear as well as non-linear "elements", and the mechanical properties are quite different from person to person. Biologically the situation is by no means simpler, especially when psychological effects are included. In considering the response of man to vibrations and shocks it is necessary, however, to take into account both mechanical and psychological effects.

1.1 Measurement of human vibration

Techniques for measuring vibration exposure have for many years been less coordinated than desirable. The data presented sometimes lack proper description of the instrumentation used to acquire it and of the important instrumentation characteristics. The descriptors used to characterize a signal are very important.

1.2 The effects of vibration on the human body

Vibrations influence the human body in many different ways. The response to a vibration exposure is primarily dependent on the frequency, amplitude, and

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duration of exposure. Other factors may include the direction of vibration input, location and mass of different body segments, level of fatigue and the presence of external support. The human response to vibration can be both mechanical and psychological. From an exposure point of view, the low frequency range of vibration is the most interesting. Exposure to vertical vibrations in the 5-10 Hz range generally causes resonance in the thoracic-abdominal system, at 20-30 Hz in the head-neck-shoulder system, and at 60-90 Hz in the eyeball. When vibrations are attenuated in the amount of mechanical energy transmission due to vibrations is dependent on the body position and muscle contractions. In standing subject, the first resonance occurs at the hip, shoulder, and head at about 5 Hz. With subjects sitting, resonance occurs at the shoulders and to some degree at the head at 5 Hz. Furthermore, a significant resonance from shoulder to head occurs at about 30 Hz as shown in Figure 1. Based on psychological studies, observations indicated that the general state of consciousness is influenced by vibrations. Low frequency vibrations 1-2 Hz with moderate intensities induce sleep. Unspecific psychological stress reactions have also been noted (Guignard, 1965: von Gierke, 1964), as well as degraded visual and motor effects on functional performance. Some symptoms of vibration exposure at low frequencies are given in Table 1, along with the frequency ranges at which the symptoms are most predominant.

Table 1. Symptoms due to whole-body vibration and the frequency range at which they usually occur (adapted from Rasmussen, 1982)

Symptoms	Frequency (Hz)
General feeling of discomfort	4-9
Head symptoms	13-20
Lower jaw symptoms	6-8
Influence on speech	13-20
"Lump in the throat"	12-16
Chest pains	5-7
Abdominal pains	4-10
Urge to urinate	10-18
Increased muscle tone	13-20
Influence on breathing movements	4-8
Muscle contractions	4-9

2. Vibration syndrome

The upper extremities of the human being can be considered a unique body segment. As with whole body vibration, the response to segmental vibration depends on frequency, amplitude, etc. Segmental vibration causes a symptom complex usually referred to as vibration syndrome. The symptom originates from injuries to the blood vessels, nerves, bones, joints and muscles. Injuries can occur after exposure times from months to decades, and are usually, at first, reversible.

The most well-known of these symptoms is Reynaud's Syndrome or Traumatic Vasopastic Disease (TVD) (Taylor, 1974). In industry is called the white finger disease/syndrome. The syndrome can be described as a sudden block in the blood circulation to the fingers, which become white, pale, cold and sometimes painful. Tactile sensitivity is reduced, preventing precision work. TVD is caused by smooth muscle constriction in the blood vessels of the fingers. Other vibration-induced symptoms come from the peripheral nerves and consist of paresthesias and tingling sensations. A decreased nerve action-potential conduction velocity has been found, and a decrease in the ability to perform precise motor movement of the fingers.

2.1 Transmission of Vibration in the Upper Extremity.

Most hand held tools generates random vibration over a wide frequency range (typically 2 – 2000 Hz). Low frequency vibrations can be transmitted to the trunk and head. It may cause unspecific symptoms such as headache, vertigo, nausea, and psychological stress reactions. Attenuation occurs with 3 dB/octave in the frequency range of 20 – 100 Hz. The attenuation of the elbow and upper part of the arm increases by about 10 dB/octave between 100 & 630 Hz, and the wrist by about 6 dB/octave.

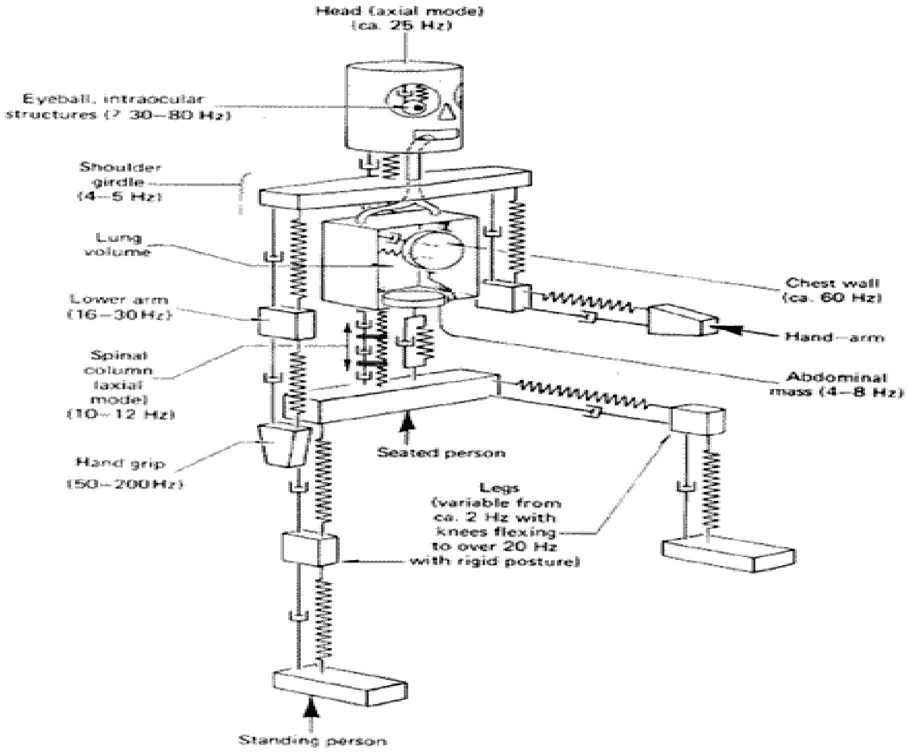


Fig. 1. Simplified mechanical system representing the human body standing on a vertically vibrating platform.

Iwata (1972) found that the vibration at the wrist was two to three times higher at 20 Hz that the input vibration; that is, resonance had occurred. The transmission of vibrations in the upper extremity is linear when the vibration of hand-held tool increases by 10 dB. The hand grip force is important to the transfer function. When increased from 20 N to 40 N 912 dB), the hand vibration increases only by 3 to 5 dB. It appears that the transmitted vibration is proportional to the cube root of the hand grip force (Pyykko et al., 1976).

3. Experimental device

Fig. 2. Soundbook.

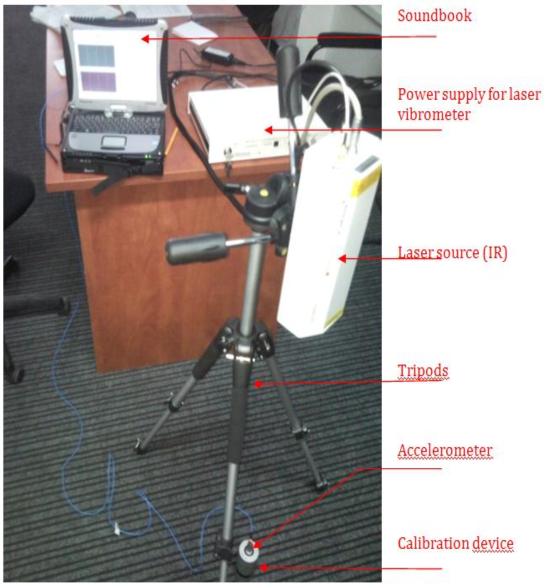


Fig. 3. Laser Vibrometer.

For the "LOW" range, the sensitivity should be around 200 V/m/s, and for the "HIGH" range, around 10 V/m/s. You have to choice LOW or HIGH range depending on the velocity of the target (Equations are in the user manual). You have to know that the two scales are the same on a large bandwidth. This choice is made on the power supply AND on the Soundbook witch the choice of the transducer. The low pass filter basically blocks all frequencies larger than its value. This is used to "clean up" the data. The signal is an AC signal. The FM output is a 10.7 MHz frequency modulated signal that is available for customers who want to implement their own demodulation strategies. However, if you want the velocity vs. time, the analog velocity output is the one to use. Soundbook is a portable system of acoustical and vibratory measure. It can be used as a part of an application of engineering in general. It is equipped with the software SAMURAI which allows the acquisition, the treatment and the exportation of different data.

For the measurements that we made we used equipment provided by the Optimum Laboratory of the IMST faculty.

The vibrations were measured using the triaxial accelerometer, the soundbook laptop and the Samuray program. For the measurements we applied the triaxial accelerometer on different key elements of the vehicle which helps transmitting the vibrations from the car to the body.

Measurements were realized at the rotational frequencies of 700-750 RPM, 1500 RPM and 3000 RPM on Dacia Berlina 1310 – 1.4 gasoline, Dacia Logan – 1.4 gasoline, Opel Astra Hatchback – 1.6 gasoline, Opel Astra Sedan – 1.4 gasoline and Mercedes C200 – 2.1 diesel.

The main condition of the measurements is that the car rotational frequency to remain constant during the experiment. If the rotational frequency varies the measurements results may be affected. Using the Samuray program we made the analysis of the experimental results.

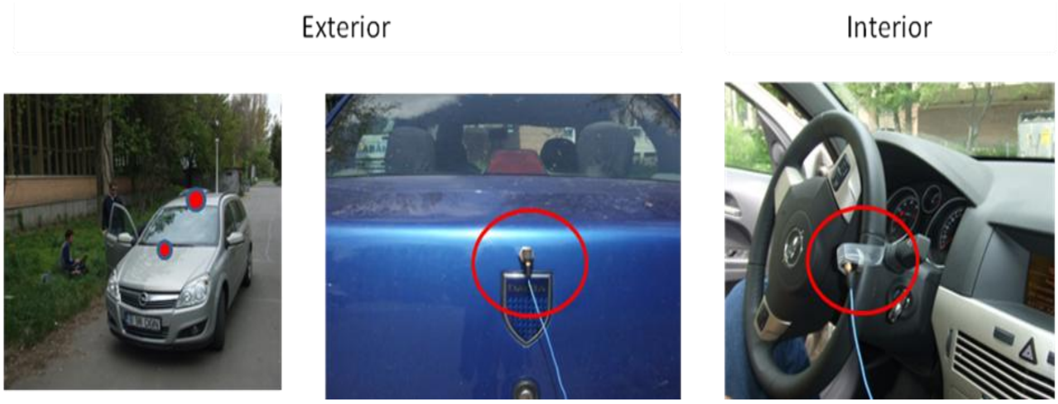


Fig. 4. Measurement points.

a. The triaxial accelerometer positioned on the exterior elements of the car

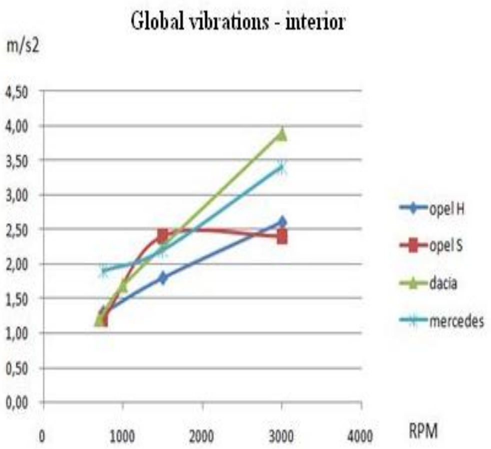
b. The triaxial accelerometer positioned on the car's trunk

c. The triaxial accelerometer positioned on the car's steering wheel

4. Experimental results and analysis

Following the analysis of the experimental results, we introduced in Microsoft Excel the obtained data where it has been processed and integrated into the diagrams below as being able to graphically highlight the vibrations generated by vehicles at the interior and exterior.

From our measurements we discovered that vibration amplitudes increase along with increasing RPM. We also observed that Dacia 1310 has the highest vibration level in the interior and Opel Sedan Classic has the highest vibration level at the exterior of the car.



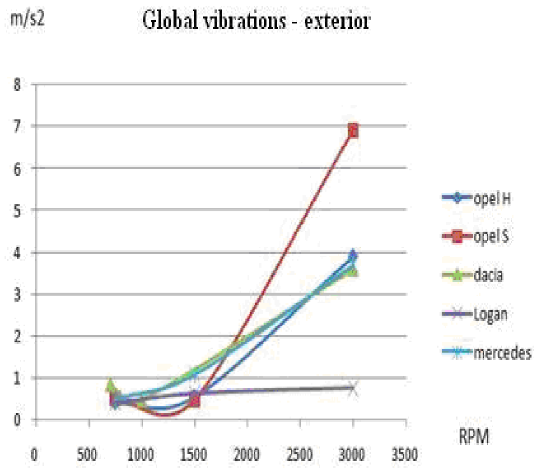


Fig. 5. Global vibrations evolution.

a. Table chart for vibrations measured in the interior of the vehicle.

b. Table chart for vibrations measured in the exterior of the vehicle.

In the following pictures on the black background are represented the global vibrations of four different vehicles and in the other three corners are represented the FFTs (Fast Fourier Transform) on all three axes of the Cartesian system.

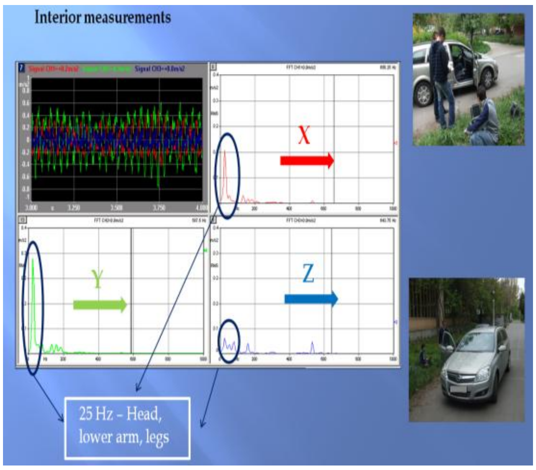


Fig. 6. 750 rpm Opel Astra Hatchback.

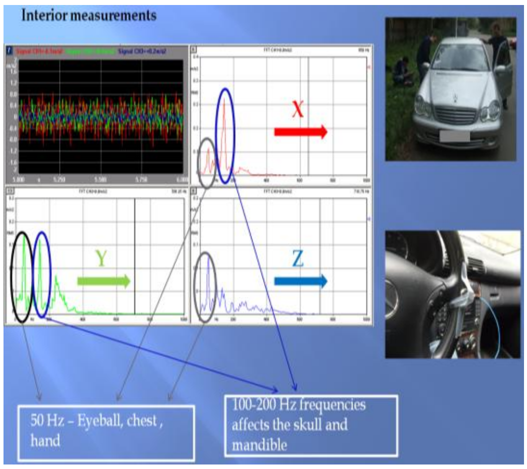


Fig. 7. 1500 rpm Mercedes C200**.**

Different parts of the human body are affected by different frequencies of vibration. In Fig. 6 we observe that the 25 Hz frequency at 750 rpm affects the head, lower arms and legs. At the frequency of 1500 rpm in Fig. 7 the eyeball, the chest and the hands are affected at the frequency of 50 Hz. Frequencies between 100 and 200 Hz affects the skull and the mandible.

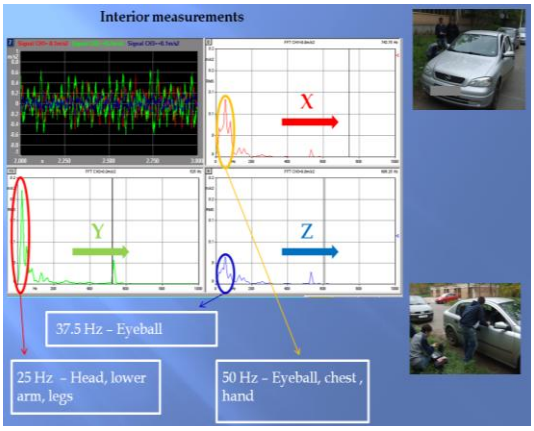


Fig. 8. 750 rpm Opel Astra Classic.

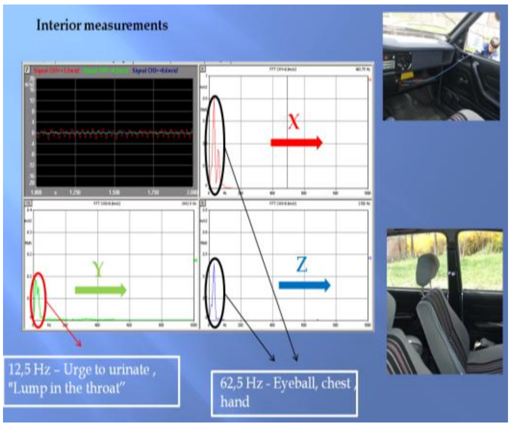


Fig. 9. 700 rpm Dacia 1310.

In Fig. 8 and 9 we measured vibrations between 12.5 and 62.5 Hz. We observe from Fig. 8 that 37.5 Hz frequency affects the eyeball and from Fig. 9 that 12.5 Hz frequency cause the symptoms of a lump in the throat and a urge to urinate and the 62.5 Hz frequency affects the eyeball, the chest and the hands.

All the measurements were made in the interior of the cars.

5. Concluding Remarks

(1) The automotive industries strive to reduce vehicle vibration, in particular its transmission to the seats. It has been shown that vibration increases discomfort and reduces operator performance.

(2) Excellent massage systems should be able to enhance the comfort of truck muscles, but not increasing discomfort (Seroussi et al., 1987 indicated that vibration significantly increases truck muscular activities when compared to static loading using EMG techniques.

(3) Resonance frequency must be avoided; in particular, frequencies in the range of 5 Hz. It may not be easy to avoid these frequencies when a massage system based on the concept of vibration is integrated to automobile seats. Combined vibrations from various systems may generate undesirable resonance

(4) In the future we need to discover more solutions for vibration damping;

(5) We need to find methods to amortize vibrations out of range of 20-60 Hz because they are most frequently found and they also are most harmful;

(6) We need to make a detailed analysis identified frequencies between 20-60 Hz in all car models measured. These common influences eyeball, chest, head, arms and legs.

R E F E R E N C E S

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