654. Measurement and comparison of energy of mechanical vibrations absorbed by humans

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(Received 2 May 2011; accepted 5 September 2011)

Abstract. Human body responds to mechanical vibrations differently. Vibrations cause various types of damage to human organism. There are two main types of effects: short-term and long-term ones. The former cause tiredness, drowsiness and focus loss. While the latter induce mechanical damage to the individual organs such as skeleton, joints, nervous system. Influence of mechanical vibrations on human body is assessed by different parameters including amplitude, frequency, duration of action, acceleration etc. The next evaluation parameter might be energy. This article reports on the laboratory measurements of absorption of mechanical vibrations by humans. From our perspective, the short-time damage to human is mainly caused by absorption of vibrational energy and long-term damage - by mechanical vibration itself. A bio-dynamic system represents human body located in an automobile seat. The source of vibrations simulates car body movements generated during driving. The energy is measured in several levels because of the description of energy flow system. The primary aim is to determinate the level of the vibrational energy that enters into a human body and is subsequently absorbed. This is considered in terms of level and spectrum of input mechanical vibrations. Based on the findings, it is possible to evaluate the level of absorbed energy and compare for the sample of population.

Keywords: mechanical vibrations, energy, dissipation, bio-dynamic system, tiredness.

Introduction

Mechanical vibration is the most common form of movement in mechanisms. The transfer of mechanical energy is characterized for the vibration. The most common approach to human body is like a mechanical system composed of sub-masses, stiffness, elasticity and mechanical resistance. Human reaction is mainly influenced by posture (sitting, lying) in relation to the direction and the intensity of input vibration. Tolerance to the vibrating body loading is the ability of a body to withstand and adapt to the effect of mechanical vibration. It is possible to distinguish the lower and upper limits of physiological tolerance and adaptability of the organism to mechanical stress [1-4]. Human body represents a damped biomechanical system, i.e. without the supply of the energy the oscillations expire after certain time. Human body dissipates the mechanical energy. The damped energy is converted into the heat energy. Human exposure to intense vibrations always causes an adverse response of the human body (injury). The greater the degree of dissipated energy, the more is the overheating of the human organism.

Human vibration measurements are analyzed by standard methods [1-4]. The basic quantity used to describe the mechanical motion is acceleration, expressed as an effective value a_{ef} [m/s^2]. Vibration may be described by using the speed and deflection of mechanical movement, however, due to vibration recording the accelerometers are used.

The adverse effects of noise and vibration protection are generally regulated by law and labor, both as amended. Long-term exposure to whole-body vibration is most often associated with the vehicle control and mobile machines. The main objective of applied research described in the article is to reduce the influence of mechanical vibration to a seated human. It is based on elimination or substantial reduction of emissions directly at the source of vibration-seat. The seat must serve as a vibration absorber.

Standardized laboratory measurements of seating human

Vibration sources used for laboratory measurements must at least contain the typical values measured using the machine under operating conditions, e.g. driving a car. It must be frequency weighted acceleration RMS value as defined in the standards [1-4]. This article presents measurements of six persons (3 men, 3 women) (Fig. 2). Standardized laboratory measurement arrangement is defined as in Fig. 1. There are two workplaces (Fig. 1) in our laboratory. The first workplace imitates the real conditions in a car and the second follows the standard laboratory conditions.

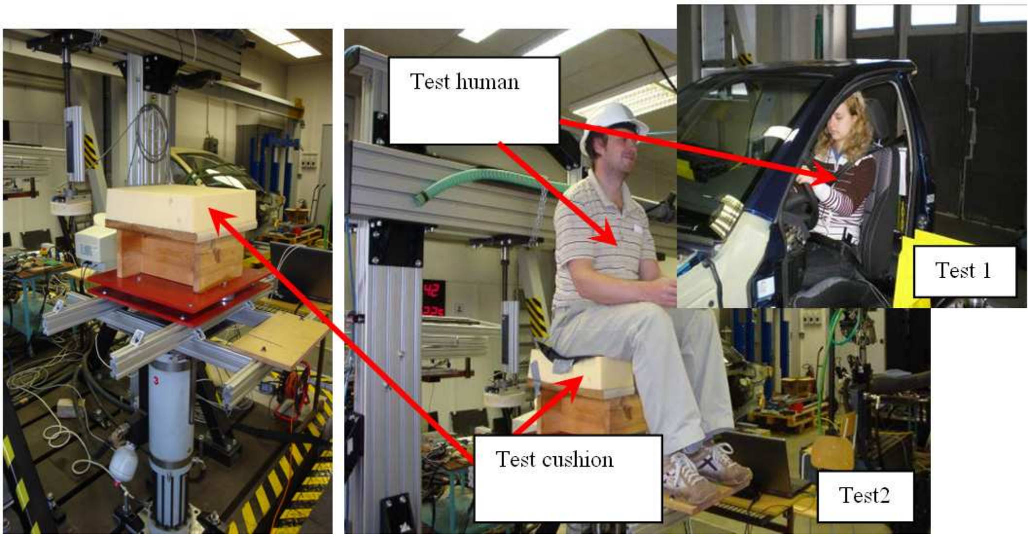

Fig. 1. Standardized laboratory measurements

Fig. 2. Standardized laboratory measurements involving humans

The hydrodynamic (HDB) exciter is used as the source of vibration. Forces and pressure sensors X-Sensor are used for measurements. Accelerations are measured with MEMS inertial sensor. Excitation signals and calibration of sensors are provided in the laboratory. Test subjects were selected according to [1-4]. The energy balance in zone 1 and 2 is evaluated by using power computation. The forces F_1, F_2, a_1 and a_2 were measured; velocities v_1, v_2, energies E_1 and E_2 were computed.

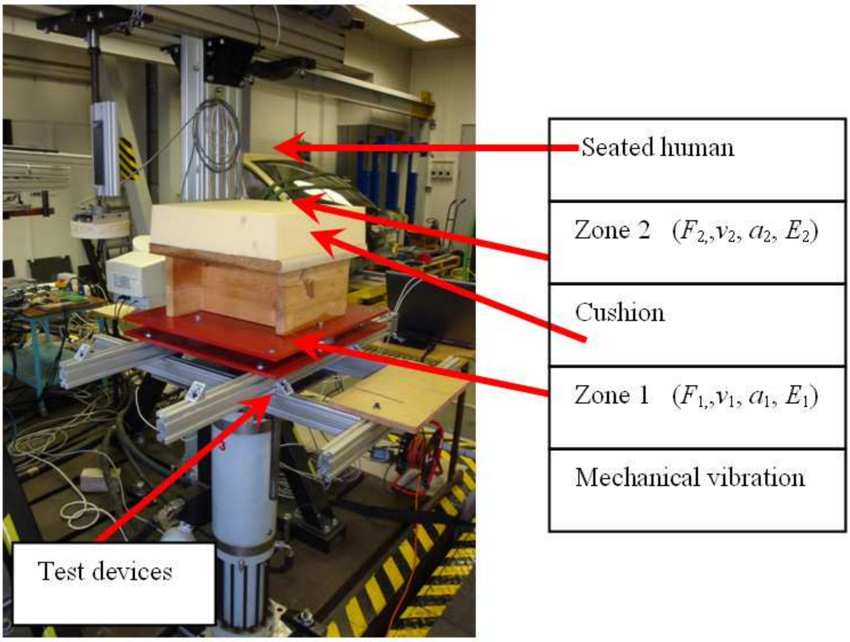

Fig. 3. Measurement setup

Analysis of measured parameters

Measured values are presented in Figs. 4-5 and Table 1. The following observations may be made. Firstly, the input vibrational energy is different for each person and lies in the range from 38.32 to 51.45 J, i.e. the correlation with person weight from 38.83 to 73.44 kg. For masculine constitution - 41.76-51 J, for the feminine - 38.32 to 46.76 J. Dissipation factor (ratio of energy dissipated to the total input energy) is in the interval from 0.306 to 0.696. It is evident that the human organism behaves quite well, i.e. correlation with biomechanical structure of the human body; from 0.617 to 0.696 (the ratio is constant). It is very interesting that men dissipates energy in the interval from 13.74 to 20.39 J and women from 10.71 to 14.64 J with the same dissipation factor. This means that the vibrational load is the same for men and women. The vibro-isolation load increases during increase of dissipated energy. The calculated average of dissipated energy in 4.5 hours (the safety break for drivers, Regulation EC 561/2006) is 720 J. If we talk about correlation with fatigue, we can predict that the human body will be overheating by dissipated energy. In conclusion we can say that each persona after a time of exposure to mechanical vibrations will get short-term damage. The nervous system is overloaded by the increase of the human body temperature (the feeling of fatigue, restless).

Conclusions

Measurements of dissipated energy layers are very important for determining the effect of mechanical vibration on the human organism. Finding correlations between the level of absorbed energy and changes in the human body, i.e. the increase of temperature, enables to predict the possible short-term phenomena such as fatigue, loss of attention, headache, fatigue, nervous system, visual difficulties. An important field is related relaxation of dissipated energy and the prevention. The fact that the human body absorbs the energy of mechanical vibrations is well-known [1-4], but an open question is how to lose this energy (cooling of human body). Also, it is not known exactly why the human body reacts differently, i.e. short and long-term relaxation at the same level of dissipated energy. It is necessary in the future research work to explore all these areas, propose recommendations to qualified manufacturers of seats and formulate recommendations on relaxation for the car drivers.

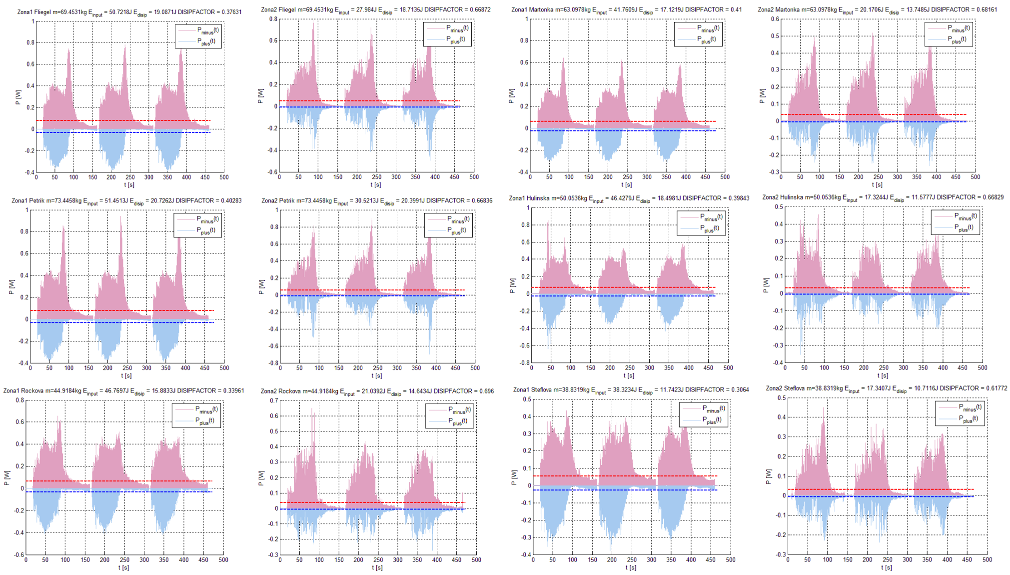

Fig. 4. Power time history in Zone1 and Zone2 for all persons

Table 1. Analysis of measured parameters for all persons

		Zone 1			Zone 2		
Person	M [kg]	E_{input1} [J]	E_{dis1} [J]	$FactorDisip_1$ [-]	E_{input2} [J]	E_{dis2} [J]	$DisipFactor_2$ [-]
M3	73,44	51,45	20,72	0,402	30,52	20,39	0,668
M1	69,45	50,72	19,08	0,376	27,98	18,71	0,686
M2	63,09	41,76	17,12	0,411	20,17	13,74	0,681
W3	50,05	46,42	18,49	0,398	17,32	11,57	0,668
W1	44,91	46,76	15,88	0,339	21,03	14,64	0,696
W2	38,83	38,32	11,74	0,306	17,34	10,71	0,617

Acknowledgments

This paper arised by the subvention research project of Ministry of Education of the Czech Republic under contract code MSM 4674788501.

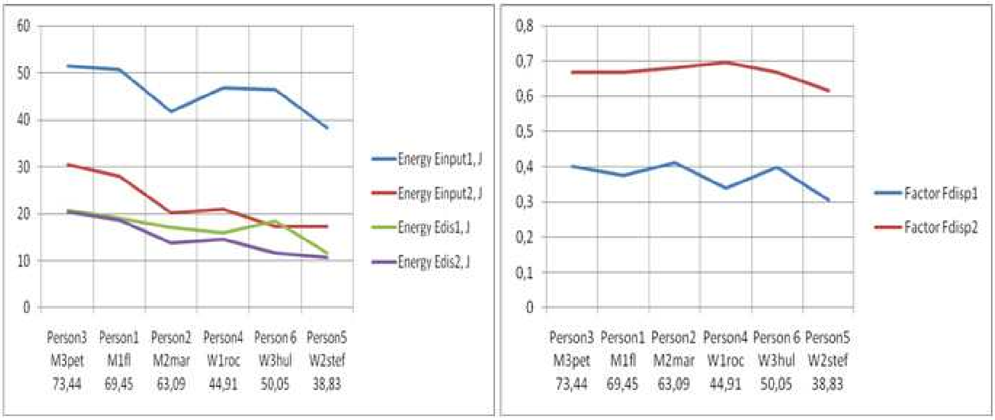

Fig. 5. Analysis of energy for all persons

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