

**COB-2019-0420**  
**EXPERIMENTAL EVALUATION RELATIVE TO WHOLE BODY  
VIBRATION (WBV) IN ARMoured VEHICLE OF THE BRAZILIAN  
ARMY**

**Mário Fedatto Neto**<sup>1</sup>

**Herbert Martins Gomes**<sup>2</sup>

**Leonardo Menna-Barreto Martinelli**<sup>3</sup>

Federal University of Rio Grande do Sul, UFRGS, 425 Sarmiento Leite Av., 90150-002, Porto Alegre, RS, Brazil.

<sup>1</sup> mariofedatto@hotmail.com

<sup>2</sup> herbert@mecanica.ufrgs.br

<sup>3</sup> leomennab@gmail.com

**Abstract.** *Vibration is a physical external agent that may bring problems concerned to health and comfort when received by the human body. There are several situations where one can be exposed to vibration and, particularly in vehicles, this is evident. Assessing the levels of vibration and degree of exposure risk in these cases is important, especially when the involved activities are long term. This paper presents a study on the whole body vibration (WBV) levels in relation to health and comfort in an armored vehicle of the Brazilian Army Guarani, a wheeled transport vehicle for military personnel. An experimental test campaign was performed to investigate vibration levels in roads composed by several types of terrains. In the assessment of WBV for health (ISO 2631-1/1997), the tests carried out with this vehicle, demonstrated, in overall, an acceptable level of vibration, but on the other hand can be classified as "fairly uncomfortable to uncomfortable".*

**Keywords:** *WBV, Military Armoured Vehicle, Vibration Comfort, Health.*

## 1. INTRODUCTION

Comfort on a ride, according to Jazar, 2008, is influenced by road disturbances, especially vibrations induced by tire-ground contact and it is mainly affected by vehicle's speed, spring stiffness and damping properties of the suspension. With the continued sophistication of the civil automotive industry and the fierce competition between the various manufacturers, it is likely that the vehicles that best meet these requirements and create a perception of doing so will be the top sellers and therefore more profitable for automobile manufacturers. Therefore, designing a good suspension has become a persistent philosophy in the civil automotive industry.

Vibration, by Ragazzi and Ximenes, 2003, is described as a repetitive, periodic or random movement, around the rest position, of a structural element or part of a machine. Bruel & Kjaer, 1989, say that the vibration received by the body can be classified into two major groups, Hand Arm Vibration (HAV) and Whole-Body Vibration (WBV). The two forms can pose risks to the human being, depending on the range of intensity and the periodicity of exposure to such vibrational modulations, which can be source of discomfort and also the cause of health problems.

According to Griffin, 1990, the comfort of vehicle's occupant depends on the static and dynamic components. The static component refers to the situation where the vehicle is completely stationary, and also includes everything from visual impression to smell and to the touch feeling on the seat. A statically comfortable seat requires minimal muscular effort from the occupant to remain seated.

Govindswamy et al., 2004, already says that the dynamic component is characterized mainly by the attributes of noise, vibration and suspension hardness when riding the vehicle. Most of the vibrations experienced by the occupants are transmitted to the body by the seat. The vibration environment, the dynamic seat response and the human body response to vibration, all together and combination determine the dynamic component of the comfort of the seat. According to Griffin, 1990, the ideal seat is one that minimizes the unwanted vibration exposition for the occupant from the relevant environment vibration.

As reported by many epidemiological studies on back pain in drivers, this occupational disease happens in association with the exposure to whole-body vibration in vehicles with high levels of vibration. Therefore this has been researched in several vehicle's segments: agricultural tractors, rally cars, buses, helicopters, trains, military vehicles, boats, just to name a few.

According to Palmer et al., 2000, the vibration is pointed out as one of the most common occupational agent, strictly linked to the onset of back pain in professional drivers. Chaffin et al., 1999, present a biomechanical model indicating

that the resonance occurs at different frequencies for different points of the human system and observed that exposures to vertical vibration, in the range of 5 to 10 Hz, cause resonance in the thorax-abdomen system and in the frequency range of 20 to 30 Hz, cause resonance in the head-neck-shoulder system. Panjabi et al., 1986, reported that transmissibility in the spine is higher in the range of 4 to 5 Hz and that many motor vehicles have frequencies in this particular range, thus being potential sources of risk to the spine's health. Figure 1 shows the the military vehicle focus of this study.



Figure 1. Armoured wheeled vehicle Guarani (IVECO S.A.)

The objective of the present study is to evaluate experimentally the vibration levels of an armored vehicle concerning comfort and health. The study is restricted to whole-body vibration analysis, using *in situ* vibration measurements in regular situations and using seatpads, accelerometers and a data acquisition system. Depending on the design and construction of these vehicles to meet specific operational needs, the vibration levels of driver and passengers are higher than usual values in civilian vehicles.

## 2. LITERATURE REVIEW

The analysis of vibration and evaluation of the effect on vehicles's drivers and passengers is a very comprehensive topic in the world literature. In most of the papers, the focus is to evaluate the harmful effects that the vibration can bring to vehicle's users as well as forms of seat improvements.

In compliance with Falk, 2004, Hohl, 2006 and Rozali et al., 2009, military vehicles comprise a wide range of vehicle types, from armored vehicles with tracks, to wheeled trucks and off-road jeeps. They are categorized into armored vehicles with track and armored vehicles with wheels. Armored vehicles with track are superior to armored vehicles with wheels on soft ground, crossing trenches and having greater mobility. Armored vehicles with wheels are suitable for combat due to the developed high speeds and the fact they can be deployed in large numbers.

According to Hung et al., 2015, the level of vibration in armored vehicle is an important aspect to consider because of the effects on human health, crew fatigue and mechanical system reliability. Reducing vibration in armored vehicles is necessary to ensure efficiency in passenger's transportation, keeping their attention and agility for combat. In that article it is highlighted how human health is affected by the exposure to vibration and the most relevant standards used to monitor and quantify its effects. It discusses three approaches to reduce vibration in the vehicle and suggests practical measures that can be taken for armored vehicles.

Fedatto Neto, 2016, cites the appearance of the vibratory resonance phenomenon related to reported problems consistent with the human body frequency range for vibration. People who are subjected to long-term, daily vibrations within that body natural frequency ranges have a high likelihood to present problems in the spine, with pains and discomforts in the lumbar region, which supports most of the body weight.

A discussion of active and passive suspension in armored vehicles is brought by Srinivasan et al., 2016. They claim that the performance of these types of vehicles is often limited by crew resistance to withstand the transmitted shocks and vibrations and also their ability to maintain control. To withstand such shocks and keep the vehicle's high mobility, they are equipped with passive suspension systems using torsion bars and shock absorbers to mitigate ground-induced shocks and impact vibrations.

Fedatto Neto et al., 2018, experimentally evaluated the exposure to vibration in car drivers with the aim to predict possible risk of spine injury as function of floor to the seat transmissibility. The study comprised six different car models.

A study on the risk of whole body vibration exposure in non-military armored vehicle drivers is presented by Degan et al., 2016. A total of 14 subjects, classified according to their body mass index, were evaluated under urban use conditions. The results clearly indicated that there is a relationship between exposure and intensity with the type of vehicle used. Surprisingly, armored vehicles presented the lowest vibration levels with respect to not armored vehicles.

Measurements of noise and whole body vibration were performed by Nakashima et al., 2007, on vehicles of the Armed Forces of Canada. The vehicles studied were the LAV III, Bison and M113A2 ADATS. Measurements were made at different positions of the crew while the vehicles were driven at different speeds, terrain and paved roads. They reported that the vector sum of the vibration magnitudes for LAV III and Bison were relatively low during road driving (0.3 m/s<sup>2</sup> for both vehicles) compared to off-road driving (0.71 and 1.36 m/s<sup>2</sup>, respectively). M113A2 ADATS vibration increased with driving speed (from 0.62 m/s<sup>2</sup> to 8 km/h to 1.26 m/s<sup>2</sup> at 32 km/h). For all measurements, the Z axis was always the dominant axis of vibration. In the case of the driver of the LAV III and Bison driving on rough terrain, and the M113A2 ADATS driver, at the driving speeds tested, the exposure will exceed the action value prescribed by the European Directive (2002), that is 0.5m/s<sup>2</sup> for 8 h. Considering the rms acceleration values obtained in the work the authors warn that this is cause for concern for the health and safety of the drivers of these armored vehicles.

In overall, in the case of armored military vehicles, the main causes of vibration transmitted to passengers and drivers are from the terrain, the specific type of vehicle design, engine, braking and acceleration. Part of the vibrations coming from the track are partially absorbed and attenuated by the suspension system, but low frequency impacts and vibrations are hardly attenuated. Important aspects related to the positioning of passengers and drivers in relation to the position of the CG may also affect the level of sensed vibration.

### 3. NORMATIVE THEORETICAL BASIS

International Standard Organization (ISO), develops and publishes International Standards concerning several topics. According them the mechanical vibration felt by the human body most of time is considered to be complex, containing multiple frequencies, occurring in more than one direction and at various points of contact with the human body. In addition, its level may change over time, and its effects may be diverse. Exposure to whole body vibration causes a complex distribution of oscillatory movements and forces within the body, and there may be variations between subjects with respect to biological effects. This type of vibration is found in vehicles, machinery, buildings and nearby work environment machinery. From a vibrational point of view, the ISO 2631-1/1997, refers to Mechanical Vibration and Shock - Evaluation of Human Exposure to Whole Body Vibration, corresponding to whole body vibration (WBV) and excludes dangerous effects of vibration transmitted directly to the limbs.

Part 1 of ISO 2631 defines methods for measuring periodic, random, and transient whole-body vibrations, indicating the main factors that combine to determine whether the degree of exposure to vibration can be considered acceptable. It is applicable to movements transmitted to the human body as a whole through the surfaces such as: feet, buttocks, back or support area of a reclining person. It is reported as frequency range of interest: 0.5 Hz to 80 Hz for health, comfort and perception.

The ISO 2631-1, 1997, establishes the use of the daily exposure value  $A_{(8)}$  given by Eq. 1 below:

$$A_{(8)} = a_{ve} \sqrt{\frac{T}{T_0}} \quad (1)$$

where,  $a_{ve}$  is the equivalent total vibration for cases where exposure to vibration occurs over two or more periods for different durations and magnitudes that correspond to the total vibration duration;  $T_0$  refers to a duration of 8 hours; and  $T$  is the time of the exposure.

In general, most of standards defines (explicitly or implicitly) two limit values that can be used to situate the  $A_{(8)}$  value:

a) EAV (Exposure Action Value) refers to the daily exposure value which, if exceeded, informs the need for measures in order to attenuate the vibration level, even though it does not pose necessary health risks;

b) ELV (Exposure Limit Value) indicates, if exceeded, the high occupational health risk in the evaluated event. In view of the high health risk, immediate action should be taken to reduce the levels of vibration, which can be considered unhealthy according to the standard.

The following Table 1 presents the scale that is used in relation to comfort by ISO 2631-1/1997, which represents the combined total weighted acceleration as reference (Table 1):

Brazilian Standard NR 15, Annex 8, 2014, aims to establish criteria to characterize the unhealthy working condition resulting from exposure to Hand-Arm Vibrations (HAV) and Whole Body Vibrations (WBV). In this normative, the technical procedures for the quantitative evaluation are referred to what is established in the Occupational Hygiene Standard (NHO) of FUNDACENTRO.

According to NR 15, 2014, the unhealthy condition for HAV is characterized if the daily occupational exposure limit corresponding to an acceleration value resulting from normalized exposure (aren) is larger than 5 m/s<sup>2</sup>. And, the unhealthy condition for WBV is characterized if the daily occupational exposure acceleration exceeds 1.1 m/s<sup>2</sup>, or the resulting Vibration Dose Value (VDV) of 21.0 m/s<sup>1.75</sup>.

Table 1. Confort scale regarding ISO 2631-1/1997.

Vibration Range [m/s <sup>2</sup> ]	Comfort Index
Less than 0.315	Not Uncomfortable
0.315 – 0.63	A Little Uncomfortable
0.5 – 1.0	Fairly Uncomfortable
0.8 – 1.6	Uncomfortable
1.25 – 2.5	Very Uncomfortable
Greater than 2.0	Extremely Uncomfortable

The situations of exposure to HAV and WBV higher than the limits of occupational exposure are characterized as unhealthy in medium degree. The quantitative assessment should be representative of the exposure, covering organizational and environmental aspects that involve the worker in the exercise of his duties. The limit values for WBV used in this work follow ISO 2631-1, 1997, and NR-15, 2014. Table 2 shows these values.

Table 2. Vibration limit values for WBV according to ISO 2631-1/1997 and NR-15/2014.

Thresholds	EAV	ELV
Daily Limit values NR-15 [2014] [m/s <sup>2</sup> ]	0.55	1.10
Daily Limit values ISO 2631-1 [1997] [m/s <sup>2</sup> ]	0.43	0.87

Brazilian Standard NHO 09 was written in 2013 in order to contribute as a tool in the identification and quantification of occupational exposure to whole body vibrations in order to collaborate in the control of exposure and prevention of occupational diseases. This technical procedure is part of the series of Occupational Hygiene Standards (NHO) prepared by technicians of the Labor Hygiene Coordination of FUNDACENTRO. Aimed at the evaluation of occupational exposure to whole body vibration, it proposes the concept of exposure component as an element to be determined by the Occupational Work Supervisor and used in the estimation of daily exposure. The purpose of this technical standard is to establish criteria and procedures for the evaluation of occupational exposure to WBV, which implies the possibility of several problems related to the health of the worker, including those related to the vertebral column. The standard applies to occupational exposure to whole body vibrations in any work situations where vibration is transmitted to the body in both the standing and seated positions. NHO 09 has as basis normative reference the ISO 2631-1/1997 (Mechanical vibration and shock - Evaluation of human exposure to whole-body vibration) and ISO 8041/2005 (Human response to vibration - Measuring instrumentation).

NHO 09 follows similar formulation and mathematical correlations to ISO 2631-1 (1997), and has the following reference values: the action level for daily occupational exposure to whole body vibration adopted corresponds to a value of the acceleration resulting from normalized exposure (aren) of 0.5 m/s<sup>2</sup> and the resulting vibration dose value (VDV) of 9.1m/s<sup>1.75</sup>; and the daily occupational exposure limit to whole body vibration corresponds to a normalized exposure acceleration value of 1.1 m/s<sup>2</sup> and the resulting vibration dose value of 21 m/s<sup>1.75</sup>.

The experimental measurement procedures that should be followed is embedded to the NHO 09 recommendations. There it is defined the location and attachment of the transducers, in which the measurements of the vibration transmitted to the body must be made simultaneously according to the three orthogonal directions using a triaxial type accelerometer. The measuring equipment, when in use, must be calibrated and in perfect electromechanical conditions. The positioning and the conduct of the evaluator should allow minimum interference in the conditions and procedures of working, aiming at not compromising the measurement. The data obtained can only be validated if the equipment maintains regular behavior throughout the measurement procedure. Table 3 shows NHO 09/2013 accleration threshold criteria for judgment and decision-making.

Table 3. Criteria for judgment and decision making by NHO 09/2013.

aren (m/s <sup>2</sup> )	VDV (m/s <sup>1.75</sup> )	Technical Consideration	Recommended Practice
0 to 0.5	0 to 9.1	Acceptable	At least maintenance of existing condition
0.5 < aren < 0.9	9.1 < VDV < 16.4	Above action level	At least the adoption of preventive measures

0.9 to 1.1	16.4 to 21.0	Region of uncertainty	Preventive and corrective measures, aiming to reduce daily exposure
> 1.1	> 21.0	Above the exposure limit	Immediate adoption of corrective measures

#### 4. MATERIAL AND METHODS

For the determination of the vibrational values effectively transmitted to the body, accelerometers were used and properly positioned in seat pads compatible with the used data acquisition equipment. The tool used to read and store the collected data was the Quest VI-400Pro portable vibration meter and analyzer, serial number 12430, with accuracy type 1 (ISO 8041) at frequency scale 1 Hz – 20 kHz, shown in Figure 2. This device has the ability to interpret the information presented of the stimuli received by the accelerometers in the axial tern x, y and z.



Figure 2. Quest VI-400Pro with seatpad, HAV accelerometer.

After properly preparing the measuring devices and storing the field data, it still remains the need to analyze all the information. The same software used in the data acquisition (Quest Suite Professional II) has post-processing capabilities and is used for the data analysis, producing graphs with all the information necessary for the evaluation of vibration. The software allows the setup of the analyzer according to the weighting curves required for the desired purpose of the analysis and with the proper set of required multiplication factors.

#### 5. RESULTS AND DISCUSSION

The study was based on a series of experimental tests, in partnership with the Brazilian Army, at the General Walter Pires Armored Training Center in the city of Santa Maria, RS, Brazil. The measurements were performed with all permissions but with limitations imposed on the use and itinerary because it involved heavy military vehicles of the Brazilian Armed Forces, not civilian vehicles, what might cause damage to the roads.

Acceleration level measurements were performed on the occupant's seat of the Guarani armored vehicle, while it was decided to transit for a period of 15 minutes/road, at a speed of 20 to 30 km/h, in sections of three different pavements: reinforced concrete pavement, parallelepiped pavement and countryside roads. Figure 3 shows the pictures of the three pavements covered by the vehicle used in this work.



Figure 3. From left to right: internal courtyard of the Armored Instruction Center, consisting of rigid pavement of reinforced concrete blocks; pavement at Boi Morto neighborhood in Santa Maria city, near the Instruction Center, composed of blocks of uneven parallelepipeds; and countryside ground road composed solely by land.

The first data set refers to the Guarani armoured vehicle seat with the vehicle passing on reinforced concrete pavement (Figure 4). The choice of measurement in the position of the occupant's seat was intentional since this contact surface between seat/driver is more intense and longstanding, for all roads tests.

Conducting the data analysis and relevant calculations for acceleration values, it was obtained an acceleration level classified as acceptable for exposure to health vibration. In addition, the measured total rms acceleration value resulted in  $0.45 \text{ m/s}^2$  which is rated, in this case, by ISO 2631 as "a little uncomfortable". By analyzing the data and the relevant calculations, it can be said that for the indicated values there is an acceptable level in exposure to vibration for health. It can be observed by Figure 7 that there are high acceleration levels at low frequencies, close to 3 Hz, which indicates, according to the Bruel & Kjaer study of 1989, that the phenomenon of resonance might be perceived in the region of the thorax, abdomen, shoulders and flexed legs. There are also some slight peaks at frequencies of 30 and 70 Hz, related to resonance in the hands, head and eye structure, however these human structures will hardly feel any more incisive effect of vibration acting in this study.

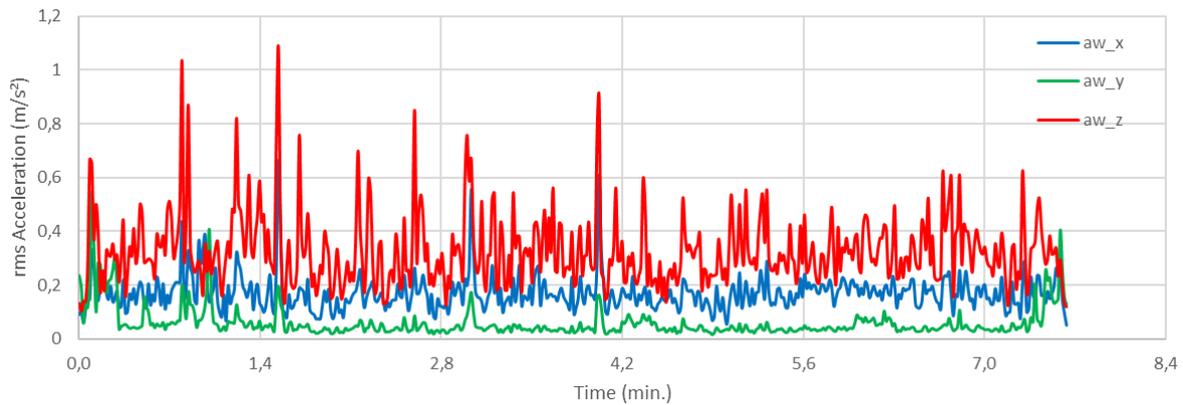


Figure 4. Time signal of triaxial accelerations, in road section of hard concrete pavement, measured in the driver's seat in the Guarani vehicle.

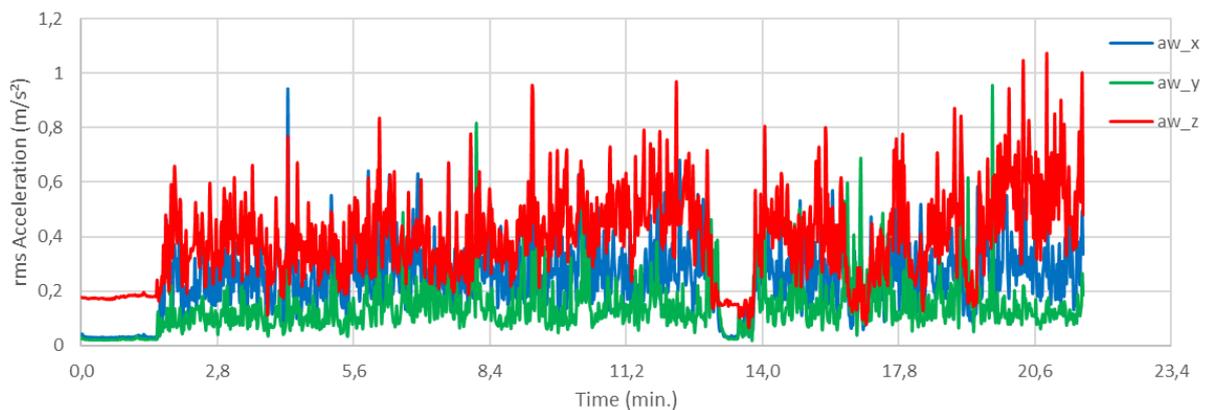


Figure 5. Time signal of triaxial accelerations, in road section of blocks of uneven parallelepipeds, measured in the driver's seat in the Guarani vehicle.

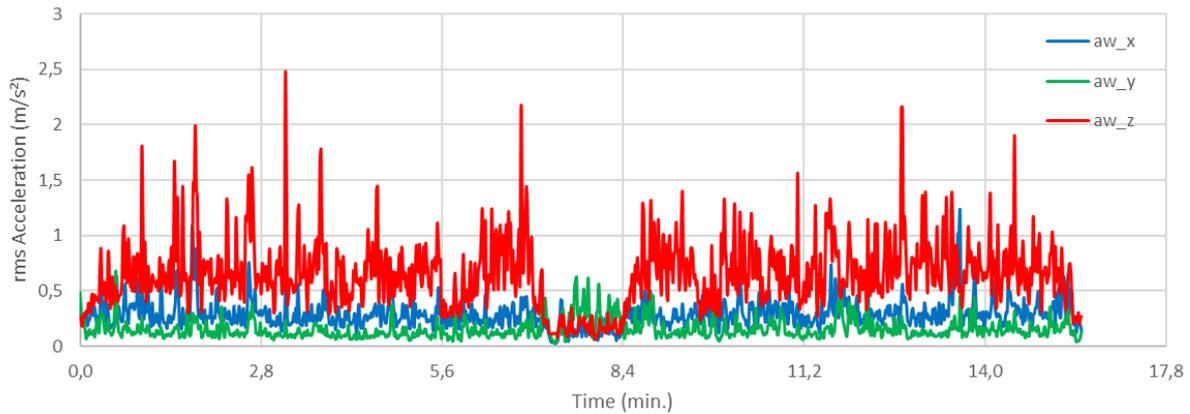


Figure 6. Time signal of triaxial accelerations, in road section of countryside ground, measured in the driver's seat in the Guarani vehicle.

The next data set refers for the Guarani armoured vehicle at the road with parallelepipeds paving, where the time signal is exposed in Figure 5. By performing the data analysis, the resulted values indicate an appropriate acceleration level concerning health exposure to vibration, and with a total rms acceleration value of 0.62 m/s<sup>2</sup>. It is concluded that this level can be considered "a little to fairly uncomfortable" in this case. The exposure action value, in this case, will be reached after more than 5h. Watching the Figure 8, it can be observed that there are higher peaks of acceleration in the low frequencies, close to 1 and 3 Hz, which indicates again that the phenomenon of resonance might be perceived in the chest region, abdomen, shoulders and flexed legs. There are also some peaks in the frequencies of 20, 30 and 40 Hz, concerning the resonance acting on hands, head, eye structure and forearm.

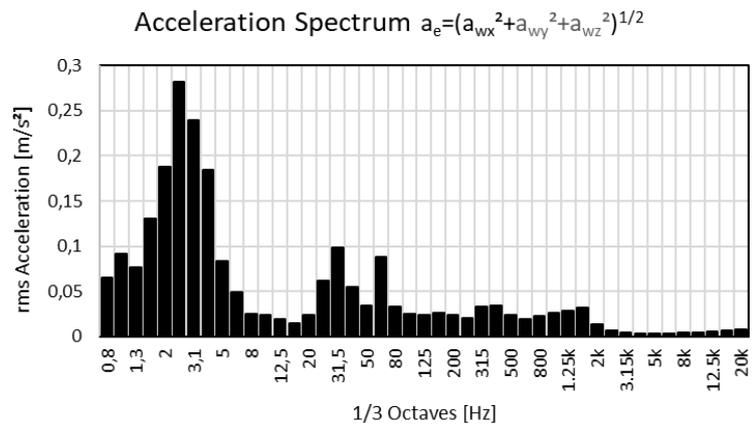


Figure 7. RMS acceleration spectrum for the Guarani armored vehicle travelling in road section of hard concrete pavement, in m/s<sup>2</sup>, measured in octave bands.

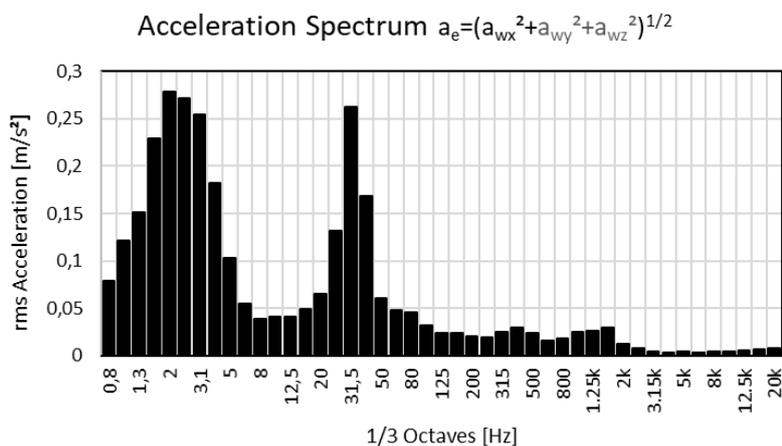


Figure 8. RMS acceleration spectrum for the Guarani armored vehicle travelling on parallelepiped road, in m/s<sup>2</sup>, measured in octave bands.

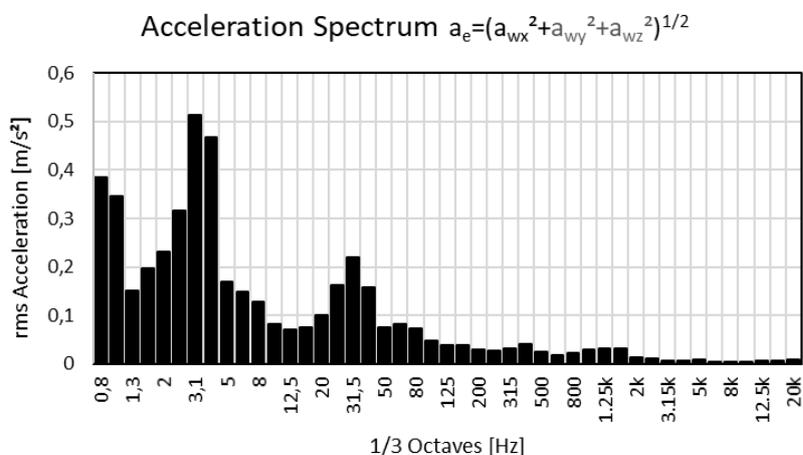


Figure 9. RMS acceleration spectrum for the Guarani armored vehicle travelling on countryside ground road, in m/s<sup>2</sup>, measured in octave bands.

In the third reading of data, it can be inferred that the values show again they may be considered at acceptable levels (Figure 6). For the measured total rms value it presents a level of vibration that can be considered "fairly uncomfortable to uncomfortable" in this case, with a measured total rms acceleration value of 0.89 m/s<sup>2</sup>. The exposure limit value, for a representative time of 8 hours will be reached in 2.55 h. It can still be observed the presence of high acceleration values in the low frequencies, ranging from 1 to 4 Hz, which indicates that the resonance phenomenon can be perceived in the region of the thorax, abdomen, shoulders and flexed legs (see Figure 9 above). There are also some high peaks in the frequencies close to 30 Hz, these referring to possible resonance that may occur in hands, head, legs in rigid posture, all ocular structure and forearm of the driver.

## 6. CONCLUSIONS

This study proposed the experimental measurement of whole-body vibration (WBV) in the Guarani military armored vehicle, measured in the seat-human body interface, traveling on three different pavements, and checking acceleration values for health and comfort issues.

For each of the proposed configurations, the respective frequency-weighted rms acceleration values were obtained for the three axes and combined as stipulated by ISO 2631-1, 1997 and also NHO-09, 2013. By the weighted partial acceleration, it was calculated the total vibration value and afterwards the acceleration resulting from the normalized exposure was also evaluated, as defined in  $A_{(8)}$ . The results obtained for the Guarani armored vehicle show that the values and exposure presents safe levels for health and it can be classified as "a little uncomfortable" and "a little to fairly uncomfortable" on concrete paved road and parallelepiped paving, respectively. On countryside road surface, again, there is a slightly high level in vibration related to health and in the overall this acceleration can be rated as "fairly uncomfortable to uncomfortable", in this case.

## 7. ACKNOWLEDGMENTS

This study was partially supported by National Council for Scientific and Technological Development (CNPq).

## 8. REFERENCES

- Bruel & Kjaer, 1989. *Primer: Human Vibration*. Ed. Bruel and Kjaer, Denmark.
- Chaffin, D. B., Andersson, G. B. J.; Martin, B. J., 1999. *Occupational biomechanics*. Wiley Interscience, New York.
- Degan, G. A., Coltrinari, G., Lippiello, D., Pinazari, M, 2016. Risk assessment of the whole-body Vibration exposure for drivers of Armored vehicles: a case study. *Int. J. of Safety and Security Eng.*, Vol. 6, pp. 53–62.
- Falk, A., 2004. Advanced mobility in difficult terrain. *Journal of Terramechanics*, Vol. 41, pp. 10-111.

- Fedatto Neto, M., 2016. *Avaliação dos níveis de vibração de corpo inteiro (VCI) em usuários de trens urbanos em Porto Alegre e região metropolitana*. Mechanical Engineering, Universidade Federal do Rio Grande do Sul, Porto Alegre, Brasil.
- Fedatto Neto, M., Gomes, H. M., Madrid, M. M., 2018. Avaliação dos níveis de transmissibilidade de vibração e predição de lesão na coluna vertebral em diferentes modelos de veículos automotores. *6º Encontro Nacional de Engenharia Biomecânica - ENEBI 2018*, Águas de Lindóia, SP, Brasil.
- Govindswamy, K., Hartwig, M.; Alt, N., Wolff, K., 2004. Designing sound to build character. *Automotive Engineering International*, Vol. 112, p. 172-76.
- Griffin, M. J., 1990. *Handbook of human vibration*. Academic Press Limited, London.
- Hohl, G.H., 2006. Military terrain vehicles. *Journal of Terramechanics*, Vol. 44, pp. 23-34.
- Hung, K. S. E., Chuan, T. T., Ann, A. L., 2015. Reducing Vibration in Armoured Tracked Vehicles. *Defese Science & Tecnology Agency - DSTA Horizons*, Vol. 10, pp. 65-76.
- ISO 2631-1, 1997. *Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration – Part 1: General requirements*. International Organization for Standartzation, Geneva, 2<sup>nd</sup> edition.
- Jazar, R. N., 2008. *Vehicle Dynamics: Theory and Application*. Springer, Berlin.
- Nakashima, A. M., Borland, M. J., Abel, S. M., 2007. Measurement of Noise and Vibration in Canadian Forces Armoured Vehicles. *Industrial Health*, Vol.45, pp. 318-327.
- NR-15, 2014. Norma Regulamentadora N° 15. Atividades e operações insalubres - Anexo N° 8: Vibrações. 24 April 2018. <<http://www.guiatrabalhista.com.br/legislacao/nr/nr15.htm>>.
- Palmer, K. T., Griffin, M. J., Bendall, H., Pannett, B., 2000. Prevalence and patern of occupational exposure to whole-body vibration in Great Britain: finding from a national survey. *Journal of Occupational Environmental Medicine*, Vol. 57, pp. 229-236.
- Panjabi, M. M., Andersson, G. B. J., Jorneus, L., Hult, E., Mattsson, L., 1986. In vivo measurement of spinal column vibrations. *The Journal of Bone and Joint Surgery*, Vol. 8, pp. 695-702.
- Regazzi, R. D.; Ximenes, G. M., 2003. *A importância da avaliação da vibração no corpo humano*. INMETRO, Rio de Janeiro, RJ, Brasil.
- Rozali, A., Rampal, K.G., Shamsul Bahri, M.T., 2009. Low back pain and association with whole body vibration among military armoured vehicle drivers in Malaysia. *Medical Journal of Malaysia*, Vol. 64, No. 3, pp. 197-204.
- Srinivasan, G., Senthil Kum, M., Junaid Basha, A. M., 2016. Performance evaluation of active suspension for tracked vehicles. *International Journal of Applied Engineering Research*, Vol. 11, pp. 331-336.

## 9. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.