23rd ABCM International Congress of Mechanical Engineering
December 6-11, 2015, Rio de Janeiro, RJ, Brazil

WORKPLACE WBV-HAV AND NOISE EXPOSURE LEVELS IN A STEEL CUTTING AND BENDING UNIT

Bruno Strebb Vieira[1]
Herbert Martins Gomes[2]
Universidade Federal do Rio Grande do Sul, Dep. Engenharia Mecânica, Av. Sarmento Leite, 425, sala 202, 2º. Andar, 90050-170 - Porto Alegre - RS - Brazil
[1]bruninho9@globo.com, [2]herbert@mecanica.ufrgs.br

Abstract. *This paper presents a research related to occupational work safety. It was conducted an assessment and mapping of potential health risks that an employee is exposed in a steel rebar cutting and bending unit, during the 8h workday journey. Two aspects were chosen for initial evaluation of the work´s health. One aspect studied is that related to the human whole-body vibration. Vibration measurements were performed at three orthogonal axes x, y and z in the workplace's platform and assessed the risk posed to workers comparing with some standards, ISO 2631(1997) and European Directive 2002/44 and NR-15(2014). The second studied aspect is the occupational noise. SPL (Sound Pressure Level) measurements were performed in the workplace, and the 1/1 octave SPL spectrum was evaluated. This make possible to assess the effectiveness of earplugs provided by the company, using two evaluation methods (complete and simplified method). It could be noticed that, in these aspects, the workplace complies with NR-15 (2014), ISO 2631(1997) and European Directive 2002/44(2002) regarding noise and vibration, thus remaining the assessment of other ergonomic aspects that may cause unhealthy effects to workers.*

Keywords: *human body vibration, occupational noise, work safety, noise and vibration measurements.*

1. INTRODUCTION

The vibration is present in many human activities and it can be defined as an oscillation of the mechanical movement. The vibrations in the industry have many sources, the main ones being those produced by transformation processes, linked to the modes of operation of the machines and materials and those caused by defects on machines (unbalance and misalignment). It is well known that the mechanical and acoustic vibrations (noise) generated in the industry, can generate uncomfortable and unhealthy working environments. Although in the case of mechanical waves, the effects caused by the vibration and the noise are different. Noise can cause problems mainly in the body related to hearing system and may generate diseases like hearing loss, in addition, can also generate fatigue, stress, headache among other effects. On the other hand, mechanical vibration can affect many parts of the body, or the body as a whole, and can cause dizziness and loss in efficiency.

According to TREBIEN et al 2010 every modern company that wants to survive and be wealth, must value the human work. The company, but a lifeline, considering individual characteristics of the human being that automatically reflects in the performance work levels and quality of life, should not see health and satisfaction as philanthropy. The working environmental conditions reflect, as stated, impacts on worker's health and well-being. Commonly evaluated aspects that are commonly evaluated one can cite ergonomics, acoustics, vibration, temperature, lighting, air quality, pressure and the presence of ionizing radiation. All these aspects, altogether contribute to the welfare and health of the environment. TOSIN, 2009 using up to date data of the Statistical Yearbook of Social Welfare, AEPS, 2010, reports that, the body parts frequently associated to occupational diseases are the shoulder 19%, the back (including back muscles , spine and spinal cord) 12.5% and ear (outer, middle, inner ear) 10.2%. These diseases can have as root causes mechanical and sound vibration (noise), so the investigation of the initial reason for the causes of these diseases is of paramount importance for society. In addition, according TREBIEN et al, 2010, the work environment can expose workers to severe vibration experienced by hands (vibrating tools), which can cause neurological damage, circulatory diseases, change in muscle strength and manual dexterity. When serious damage occurs, they are labeled as occupational diseases. Since the vibrations applied to whole body (by vehicles, vessels, vibrating floors, etc.) can cause resonances that affect viscera and particularly the muscles, skeleton and cartilage (spine) and trigger problems with equilibrium and dexterity loss as well as subjective psychological aspects as irritation and headaches. In the case of noise, if not properly monitored, it can cause discomfort or even harm to hearing health, leading to, in less severe cases, temporary hearing acuity loss or in more serious cases, lead to deafness.

1.1 Motivation

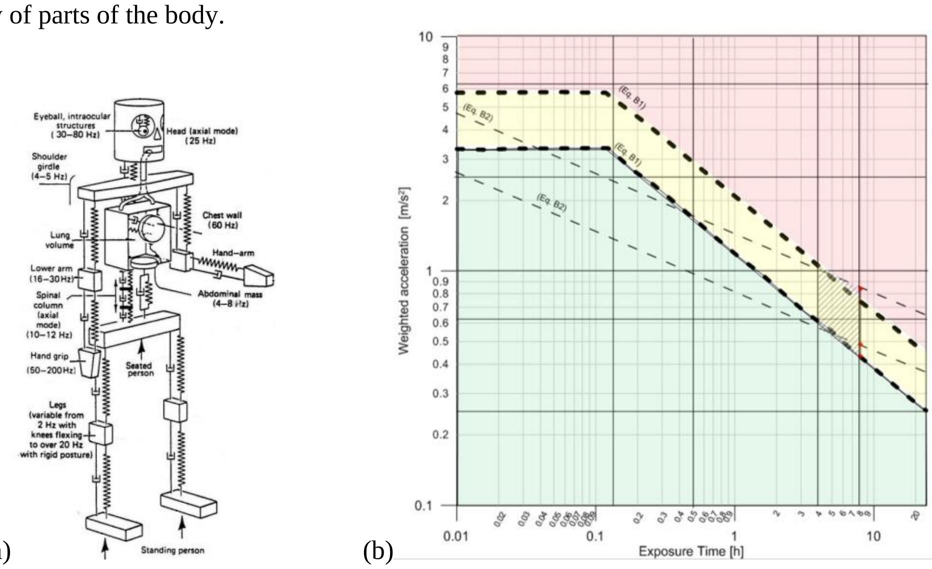
Based on experimentally collected data, Tosin (2009) and the growing industry concern about employee health, this paper makes a preliminary case study of these harmful agents in industry related to occupational effects generated by whole-body vibration and noise analysis in workplace. This study aims to assess the exposure level of vibration and noise at a steel cutting and rebar bending workplace on a regular 8h working journey. This study is triggered by complaints from employees related to discomfort in the lower back and legs, as well as headaches and exhaustion after a working day. Although the study presented here only discuss the aspects related to the vibration and noise in the activity, it is assumed that these two are, in the analyzed case, the most important aspects to be evaluated. Although other aspects such as ergonomics, temperature, air quality, etc. are not the focus of this work, although authors acknowledge the relevance are aware about related legislation. This certainly may be part of a future study for the full assessment of the health and safety in that workplace. In this work, the Brazilian Regulatory Standard NR-15 (2014) will be used to analyze the risks caused by mechanical vibration and noise. Annex 8 of NR-15(2014) deals with activities and operations that expose workers to vibration and refers to NHO-09 and NHO-10 procedures to perform measurements although vibration action and limit levels are define in accordance to NR-15(2014) (very similar to Directive 2002/44/EC (2002) threshold levels).

For the noise evaluation, Annexes 1 and 2 of the NR-15 indicate the threshold limits for continuous, intermittent and impact noise. An analysis of the efficacy of hearing protectors on noise octave bands and the characteristic sound pressure levels of the workplace is performed and evaluated whether the attenuation is sufficient to the standard limit values.

2. EFFECTS OF NOISE AND VIBRATION IN HUMAN BODY

Most human activities involve in some sense vibration. According to Soeiro (2011), the hearing process happens due to eardrum vibration, the vision happens due to light waves that reflects on objects and travel to eyes, the breathing process is associated lungs oscillations, the blood circulation is due to heart pumping, the vibration of the vocal chords produces the sound and all types of body movement is done by vibrations of our members. According Vendrame (2003), vibration consists of oscillatory movements of bodies with inherent mass and elasticity. The body is said to vibrate when it describes an oscillating movement around a reference point and the number of times a full cycle of motion for a period of one second happens is called frequency (Hertz, Hz).

If the frequency of an external load acting on a system matches the natural frequency of the system, there is the phenomenon known as resonance, which involves amplified vibratory movements. Load excitation in low damped systems at the resonance frequency can cause the system collapse, even if the excitation is of small amplitude. The human body is a complex system, and it is still difficult to define clearly the dynamic behavior. Figure 1 shows a sketch of widely used model to illustrate the resonance frequencies of the human body subjected to vertical vibration and the corresponding natural frequency of parts of the body.



(a) (b)

Figure 1. (a)Mechanical model of the human body, subject to vertical vibration with its resonance frequency (Source: Adapted from Brüel & Kjaer, 2000). (b) Daily exposure time limits as a function of the frequency-weighted acceleration for the whole body (Source: Adapted from ISO 2631-1, 1997).

The humans exposure to vibration is classified following the particularities of the kind of vibration: (a) Whole Body Vibration (WBV): are vibrations that affect the whole body and may have greater relevance to the health, comfort and perception in the range of 0.5 Hz to 80 Hz and sickness in the range 0 1 Hz to 0.5 Hz; (b) Hand-Arm Vibration or (HAV): are vibrations transmitted to the hands and arms, in a frequency range from 6.3 to 1250 Hz. It is also possible to occur simultaneous exposure of two types of vibration. (Griffin, 1998). Briefly, the effects of vibration may be listed as (Vendrame, 2005): Loss of equilibrium; changes in heart rate (increase); lack of concentration (psychological effects); blurred vision; effects on the gastrointestinal system, dizziness, nausea, gastritis, ulcers; problems of blood supply, degeneration of tissue and cartilage; loss of tactile sensation. According to Carmo (1999), the environmental noise affects the human body directly and indirectly, considering the frequency, intensity, duration and individual susceptibility. The noise acts through the hearing system in the central and autonomous nervous system. When the threshold limits are exceeded this generates psychosomatic effects ranging from dizziness, momentary hearing loss, sleep disorders and hormonal disorders to increased risk of heart attack and changes in the immune system. Such effects can be monitored and even mitigated with the development of educational programs and preventive measures for noise level monitoring. The main environmental noise effects on the human body can be summarized as follows: interference with communication; temporary changes in hearing loss and noise-induced threshold; vestibular and neurological disorders; cardiovascular disorders; hormonal disorders; sleep disorders and attention; behavioral disorders.

3. MATERIALS AND METHODS

3.1 Evaluation of vibration effects on health

For the assessment of the effects that the vibration can cause health is necessary to use a reference standard, since it aims to standardize and ensure the methodology used in many different situations, thus making them comparable. This study is based on ISO 2631-1 (1997), Brazilian Regulatory Standard NR-15 (2014) and the European Directive 2002/44/EC (2002) recommendations. The rms acceleration level is considered the most appropriate value for the analysis of vibrations (SOEIRO, 2011) and is used by most standards and academic studies. According to ISO 2631-1 (1997), the vibration must be measured following a three axis coordinate system (x, y, and z) with origin at the point where the entry is considered the vibratory movement. According to Griffin (1990), the vibration at different frequencies or in different axes, can produce different sensations/effects on different body parts, then to obtain a total weighted value of acceleration, it is necessary to sum the values of acceleration for each axis by multiplying by a weighting value or correction. For instance, the W_d weighting curves should be used for the x and y-axes, and W_k for the z-axis. The total resultant acceleration, a_v is given by $a_v = \sqrt{k_x^2 a_{wx}^2 + k_y^2 a_{wy}^2 + k_z^2 a_{wz}^2}$ wherea_{wx}, and $a_{wy} a_{wz}$ are weighted rms acceleration in m/s^2 in the direction of orthogonal axes x, y and z, k_x, k_y, and k_z are correction factors for the respective orthogonal axes x, y and z. According to ISO 2631-1 (1997), in cases where the exposure to vibration consisting of two or more periods of exposure to various durations and magnitudes of vibration, total equivalent vibration $a_{v,e}$ is estimated corresponding to a total exposure time t in hours, according to Eq (1):

$$a_{v,e} = \left[\frac{\sum a_{vi}^2 \cdot T_i}{\sum T_i}\right]^{\frac{1}{2}} \tag{1}$$

In order to determine an equivalent acceleration related to a standard period of workday of 8h ISO 2631-1 (1997) indicates the use of the following Eq. (2):

$$A(8) = a_{v,e}\sqrt{\frac{T}{T_0}} \tag{2}$$

where A (8) is the daily vibration exposure in m/s^2, $a_{v,e}$, and is the total equivalent acceleration, given by Eq. (1) , T is the daily exposure duration in h T_0 is the reference duration. Therefore, one can assume A(8) as the total value of the weighted acceleration that is exposed in a 8-hour working day for comparisons. This paper used two criteria to assess the level of exposure to vibration in relation to adverse health effects. The ISO 2631-1 (1997) indicates an action zone, indicated by the region between the dashed lines of the Eq. B.1, in Fig. 1(b). For exposures below the zone, health effects have not been clearly documented and/or observed; within the zone, it is necessary caution regarding the potential health risks and above that area, health risks are likely. These recommendations are based primarily on exposures in the range of 4 hours to 8 hours, as indicated by shaded area in the same Fig. 1(b). The other approach used is the use of the limits set by the European Directive 2002/44 / EC(2002) or NR-15(2014), which sets the value of 1.15 m/s^2 or 1.1 m/s^2 as the daily limit values and above 0.5 m/s^2 as action value where mitigation measures should be taken. This standardized limit corresponds to a reference period of 8 hours. The use Directive 2202/44/EC (2002) and NR-15 (2014) is being preferable in detriment to ISO 2631-1 (1997) because the latter indicates clear limit values instead of probable vibration effects regions. However, when comparing the standards, ISO 2631-1 (1997) presents more conservative values for a8h daily work journey.

3.2 Equipments for vibration level assessment

As previously mentioned, the best way to measure a vibration is by the rms acceleration. Therefore, this value is used in this work. For the data acquisition and analysis the following equipment were used: Quest VI-400Pro, S/N 12430, portable vibration analyzer, capable of recording data in 4 different channels simultaneously. seat pad transducer Model 070-030, S/N 646 with tri-axial accelerometer with 100.3 mV/g nominal sensitivity in each axis and Quest Suite Professional II Software to set up weighting curves and parameters for data acquisition and data analysis.

3.3 Evaluation of noise effects on health

This study uses the Brazilian Regulatory Standard No.15 (2014), which provides sound pressure level limits (SPL) for this type of exposure, depending on the exposure time (see, for instance Annex 2, NR15, 2014)). As previously mentioned, for the assessment of noise exposure levels it is necessary to use a standard exposure time for the SPL. To establish this type of evaluation of SPL at different exposure times, it is necessary to make the integration of the noise level for a certain period of time, called the equivalent sound pressure level, Leq, measured in dB (A) (Medeiros, 2011). The Leq can be calculated according to Eq. (3):

$$L_{eq} = 10\ \log\left[\frac{1}{T}\int_0^T\left(\frac{P^2(t)}{P_0^2}\right)dt\right] \tag{3}$$

where T is the integration time (usually 1s), P (t) is the instantaneous sound pressure, measured in N/m², P_0 is the reference sound pressure (2×10^{-5} N/m²). Another factor to be considered for the analysis of noise exposure in the workplace is the attenuation that eventually promoted by hearing protection devices (personal protective equipment). The evaluation of the decay promoted by the protective equipment can be done with regard to a specific frequency. Thus, one can carry out the analysis of NRRsf (Noise Reduction Rating subject fit), the personal protective equipment, called the simplified method. The evaluation of NRRsf uses the Eq. (4):

$$SPL_p\big(dB(A)\big) = NPS\big(dB(A)\big) - NRR_{sf} \tag{4}$$

If the measured Leq is less than the SPL_p, the protective hearing device is effective in attenuating the noise. Another way to evaluate the attenuation promoted by protective device is to use the frequency spectrum of the measured noise and attenuate by frequency band of the protective device given by the manufacturer (included in the CA, certificate of approval). This is called the complete method. In order to have the total noise to which the worker is exposed, one should perform the logarithmic sum of the attenuated SPL in each band frequency. Since the attenuating is performed using 2 standard deviations of the manufacturer values, this results in 98% confidence of attenuation value promoted by the device. Equation (5) shows this complete method:

$$SPL_t = 10\log_{10}\left(\sum_{i=1}^{n} 10^{[(NPS_i-(\mu_{at}-2\times\sigma_{at}))]/10}\right) \tag{5}$$

where *n* is the number of frequency bands in which the sum is performed.

3.4 Equipments for noise level assessment

The acquisition of noise in octave band spectrum was performed with the aid of a sound pressure level meter Quest model 1900, an acoustic calibrator Quest QC-20, an octave frequency filters OB-300 (octave band frequency, 11 bands and 1/3 octave band frequency, 33 bands) and a tripod for positioning the instrument. Figure 3(a) shows the equipment.

(a) (b) (c)

Figure 3. (a)Sound pressure level meter Quest 1900 model. (b) Vibration level meter Quest VI-400Pro (c) Hearing protection, (c-a) moldable earplug, (c-b) protective earplug shell, (c-c) protective precast earplug.

The hearing protective equipment for the evaluation is the same provided by the company to their employees. The evaluated hearing protective devices were three, (a) moldable insert earplug, ear shell type and precast insert earplug, as shown in Fig. 3(c).

3.5 Description of the evaluated workplace

Noise and vibration measurements were performed in the workplace that included steel cutting tasks and rebar bending. The operator of the machine FlexiPlus (Omes) performs the steel rebar cutting and sending the bars to other machine, the CS 40 (Omes) which in turn performs the bending. The activities performed by the machine operator includes the calculation of the bars cuts values, taking into account measurements in the raw material and also quality aspects such as production of parts with less waste. This is a first step in the first bar produced during the day and then is performed during the machine operating cycle, to save time. In a second phase, the operator triggers the two-hand control for the opening the cover where the rebar will perform a 180º turn. Then, with one hand, he raises the selected bars for cutting, guiding the rebar to the cutting site and then returning his body to the initial position facing the machine. Again, pressing the two-hand control to close the safety door, he triggers the machine operation to start cutting.

3.6 Vibration Measurements

The instrumentation was performed using a seat pad in the contact interface between the machine operator and the source of vibration, which in this case is the feet support platform. ISO 2631 recommendations was followed in relation to the reference position of the orthogonal measurement axes and the correct positioning of the transducers. The seat pad was positioned exactly between the operator`s feet, who leaned on the edges, as shown in Fig. 4(b). Enough measurements were taken to ensure an entire operator activity cycle. It starts with the introduction of the steel bars (which includes locking the protection device and their alignment), pulling the bars, cutting, allocating (scroll bars to the appropriate location for storage or rework through mats of polyurethane rollers), and again the pulling (the bars that have been cut, but not yet allocated) and allocating again. Before the measurements, the accelerometer sensitivity was provided for the software in each orthogonal directions. The accelerometer has sensitivity of 100 mV/g at x-direction; 98.3 mV/g in y-direction and 101.4 mV/g in z-direction. According to ISO 2631-1, 1997 to assess health effects for WBV, one should use the weighting coefficient "k" with values from 1.4 to k_x and k_y and 1 for k_z to the measured accelerations in each axis and unit "k" values to all axes in case of HAV.

3.7 Noise Measurements

In order to get the data related to the noise generated in the workplace, octave sound spectrum band frequencies using the SPL meter with a frequency band filter was used. It was checked the calibration before and after each measurement. Thus, as in the vibration data acquisition, noise measurements were carried out covering the entire cycle of operator activity. The instruments were positioned at the level of the ear, Fig. 4(a) shows the SPL meter with weighting circuit parameters at "A" slow response and limit SPL for 8h set as 85 dB(A). The integration lower threshold level was set 80 dB (A) and the measuring scale ranges from 20 to 80 dB (A) or from 60 to 120 dB (A), depending on SPL level.

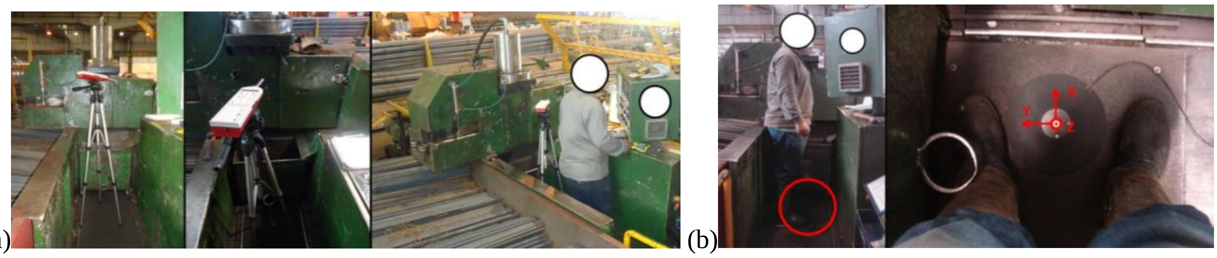

(a) (b)

Figure 4. Positioning of (a) sound pressure level meter and (b) accelerometer transducers and coordinate axis.

4. RESULTS

4.1 Vibration results

The results for vibration measurements in the workplace are shown in Fig.5.The measurements were made with three different operators even during the three working shifts. For each measurement, it was considered a representative cycle time interval. The obtained rms acceleration in each of the orthogonal axes x, y and z represented by a_{wx}, and a_{wy} a_{wz}. Using Eq. (1), this gives the total rms acceleration a_v, considered in each of the three axes. The calculation of daily vibration exposure, A(8) is carried out using Eq. (2), which takes into account the values of $a_{v,e}$ and the total exposure time which encompasses the entire cycle of activities of the operator, depending on the production operator list. In the case of the considered work this total exposure time is 8 hours (T_0).

Figure 5 depicts one cycle of the operator's entire working cycle of 21 s. The graphs shows the weighted rms acceleration in each of the stages of the cycle and in each of the orthogonal axes. Analyzing the graph, it is evident that the largest measured acceleration is mainly related to the z-axis on the steps of pulling and cutting the bars.

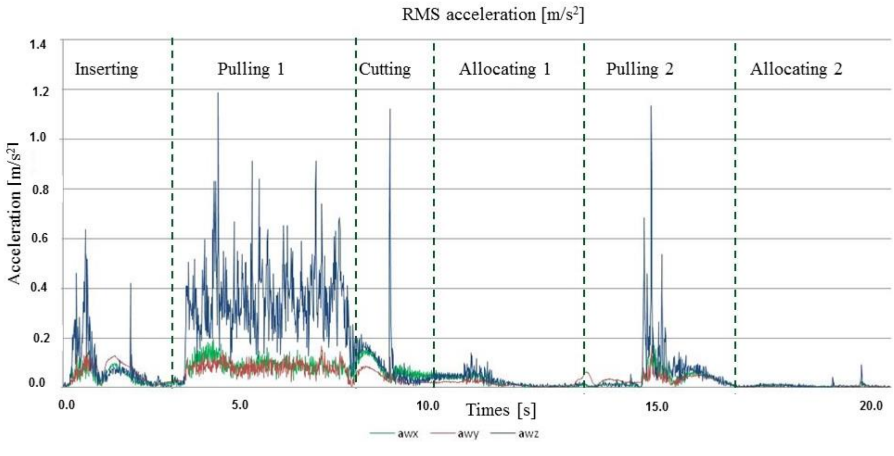
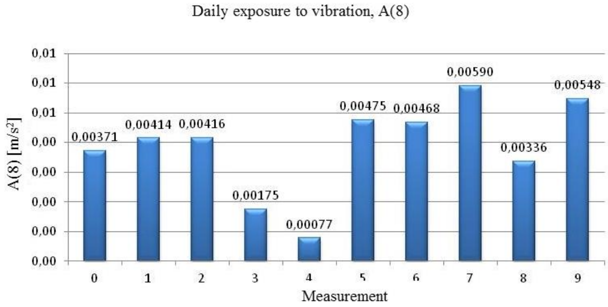
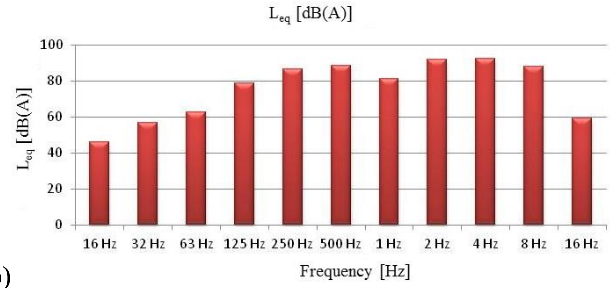


Figure 5. RMS weighted acceleration levels for 8h working day journey.

Analyzing all results summarized in Fig. 6(a), it seems that the greatest value to A(8) was recorded in measurement 7, reaching approximately 0.006 m/s^2, which is a low vibration value that does not limit the time of 8 h of exposure according to ISO 2631-1, 1997, the European Directive 2002/44/EC (2002) and NR-15(2014). The evaluation of measured vibration shows that there are no health risks from exposure to vibration during the 8h working day, despite the complaints that motivated this study. This result can be attributed to the support of the work platform that is independent of the machine (isolated) so only the vibration transmitted from the machine to the ground is perceived by the operator on the platform, thereby of less intensity.



(a)



(b)

Figure 6. (a)Daily exposure to vibration A(8) [m/s^2] (b) octave band SPL spectrum L_{eq} [dB(A)].

4.2 Noise results

The following Fig. 6(b) summarizes the main results obtained in noise measurements. The noise measurements were taken as a representative cycle of the entire workday, ranging from 19 to 25 seconds in each work cycle. For each frequency band, about 10 measurements were taken. For the noise evaluation a 1/1 octave band frequency spectrum was generated as shown in Fig. 6(b).

It seems that the spectrum is characterized by having predominantly higher midrange frequencies between 250 Hz to 8 kHz. The logarithmic decibel sum of the spectrum values gives a total SPL of 97.35 dB (A).

4.3 Hearing protective equipment

The assessment of hearing level exposure by NR 15 (2004) prescribes a maximum value of 85 dB (A) for 8h. The attenuation measurements follows the complete and simplified method. Tables 1 and 2 show the calculated data for each of the three types of hearing protective device. The attenuation data for the hearing protective devices can be found in the CA available online.

Table 1. Complete method applied to the three hearing protective devices.

Complete method applied to the precast insert protective hearing equipment. CA 8092								
Frequency [Hz]	125	250	500	1000	2000	4000	8000	SPL_t
Measurement in workplace [dB]	78.9	86.43	88.68	81.21	92.07	92.53	88.07	97.35
Attenuation [dB] μ_{at}	17	18.9	24	21.8	27.5	26.2	35.8	
Standard deviation σ_{at}	7.7	6.9	5.3	4.8	4.9	4.7	9.3	
2 × Standard deviation	15.4	13.8	10.6	9.6	9.8	9.4	18.6	
Attenuation limit (98%)	1.6	5.1	13.4	12.2	17.7	16.8	17.2	
SPL_t w/ protective hearing equipment [dB]	77.3	81.33	75.28	69.01	74.37	75.73	70.87	84.89
Complete method applied to the ear shell protective hearing equipment. CA 28089								
Frequency [Hz]	125	250	500	1000	2000	4000	8000	SPL_t
Measurement in workplace [dB]	78.9	86.43	88.68	81.21	92.07	92.53	88.07	97.35
Attenuation [dB] μ_{at}	9.7	15.7	21.3	25.1	29	24.5	23.1	
Standard deviationσ_{at}	4.7	5.4	4.1	3,0	4.4	5.2	5.5	
2 × Standard deviation	9.4	10.8	8.2	6,0	8.8	10.4	11,0	
Attenuation limit (98%)	0.3	4.9	13.1	19.1	20.2	14.1	12.1	
SPL_t w/ protective hearing equipment [dB]	78.6	81.53	75.58	62.11	71.87	78.43	75.97	85.76
Complete method applied to the molded insert protective hearing equipment. CA 5674								
Frequency [Hz]	125	250	500	1000	2000	4000	8000	SPL_t
Measurement in workplace [dB]	78.9	86.43	88.68	81.21	92.07	92.53	88.07	97.35
Attenuation [dB] μ_{at}	16.8	17.7	20.2	21.2	28.2	33.8	33.8	
Standard deviationσ_{at}	6,0	5.3	6.6	4.1	5.7	6.5	8,0	
2 × Standard deviation	12,0	10.6	13.2	8.2	11.4	13,0	16,0	
Attenuation limit (98%)	4.8	7.1	7,0	13,0	16.8	20.8	17.8	
SPL_t w/ protective hearing equipment [dB]	74.1	79.33	81.68	68.21	75.27	71.73	70.27	85.11

Observing the results of attenuation according to the complete method, one can noted that the only protective device that meets the requirements for 8h of exposure, according to NR 15, is the precast insert earplug, that attenuates 12.46 dB(A). The other two protective devices exceeds in 0.89% and 0.13% the threshold limit of 85 dB(A). These results suggest, taking into account the uncertainties inherent to the measurement, that the use of these devices is appropriate for the noise level the operators are exposed. Other key information that can be drawn from these calculations is that none of protective hearing devices exposes workers to noise exceeding the limits at specific frequency band; only at the total SPL sum, this value is slightly exceeded. It is recommended new measurements for molded insert protective device and the earplug shell since the exceedance was very low (less than 1%).

The simplified method was also used. Taking into account the total value of NPS_t in dB(A), calculating the logarithmic sum of the separated frequency bands, and performing the calculation of attenuation following Eq.(4). Table 2 shows the results.

Table 2. Simplified method applied to hearing equipment.

Hearing Device	Precast earplug CA 8092	Ear Shell CA 28089	Molded earplug CA 5674
Measurement in workplace [dB]	97.35	97.35	97.35
Attenuation NRR_{sf} [dB] - CA	16,00	15,00	16,00
SPL_t w/hearing equipment [dB]	81,35	82,35	81,35

The attenuation promoted by the three devices did not exceed the limit of 85 dB(A) for 8h a day in any evaluated protective device. The result suggests that the work assessed poses no risk to workers' hearing health. Despite the simplified method of assessment suggesting the workplace is in a safety condition, according Gerges (2000), this method has not good accuracy for the attenuation prediction; the same author also states that using the simplified method with NRRsf only 84% of users in fact may have this attenuation, leaving a large margin for uncertainty.

5. FINAL REMARKS

From the analysis of data generated by acceleration measurements at the workplace and comparing these values with those of standards used, ISO 2631-1 (1997), European Directive 2002/44 and NR-15 (2014) it is evident that there are no major risks in relation to worker exposure to vibration during the journey in this job. The vibration generated by the machine poses no risk to the worker, one of the reasons this conclusion, in addition to the measured acceleration data, the fact that the machine is not in direct contact with the work platform, since their support is independent.

One of the possible agents of discomfort and pain reported by workers in this job may be due to labor posture and other aspects of ergonomics. In its activity, the worker is standing all day long, making turning movements, over his own body, 180 °, manually lifting steel rebar rods and inserts them into the machine, forcing the spine because the storage location of raw materials is one level below the machine.

On the analysis of noise, one can see that the predominant frequency of the spectrum for the job is higher in the midrange in a zone of medium frequency discharge. This implies that the hearing protection, responsible for sound attenuation, should have a greater attenuation level in these frequency ranges.

The analysis of noise attenuation promoted by hearing protectors in relation to sound pressure levels related to frequency octave bands spectrum characteristic of the job, indicates the importance of a careful selection of hearing protection available to the worker, as this should ensure that the employee is not exposed to noise levels exceeding the limits set out in the standard. It is evident the difference in attenuation promoted by different protective devices and that the main features are not observed at a site noise, the person using the shield may be exposed to risks.

The analysis of the complete method ranked the top three ear protectors used in this study as satisfactory mitigation for this job, indicating some extra measurements for those who exceed the standard limits (less than 1%). In addition, the simplified method achieved a satisfactory result for mitigating the noise exposure, indicating that there is no risk of unhealthy labor in the workplace in relation to this method.

Although it was found that the work does not offer health risks of the operator on the two issues dealt with in this paper (vibration and noise), following the criteria adopted by the NR-15 (2014), it is necessary to keep on investigating all possible aspects of discomfort and safety in the industrial activity. This gives a glimpse for future studies of the work itself and an experience for replication studies in workplace of the cutting and bending steel rebar unit.

6. REFERENCES

AEPS. 2010. "*Anuário estatístico da previdência social. Ministério da Previdência Social*", <http://www.mpas.gov.br/arquivos/office/3_111202-105619-646.pdf>, acessed: 13 Nov. 2012.

MTE. 2012. "*Ministério do Trabalho e Emprego Sistema de pesquisa CA.*" <http://www3.mte.gov.br/sistemas/caepi/PesquisarCAInternetXSL.asp>, accessed: 18 Nov. 2012.

Brüel & Kjaer, 2000. "*Human Body Vibration*." Technical Report, 2000.

Carmo, L. I. C., 1999. "*Effects of environmental noise on human body and their hearing diseases*", Monograph of Clinical Audiology Course, CEFAC- Centro de Especialização em Fonoaudiologia Clínica, Goiania, Brazil.

Directive 2002/44/EC, 2002. "*On the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration).*" The European Parliament and the Council of the European Union. Official Journal of the European Communities, L177/13-19.

Gerges, S.N.Y., 2000. "*Noise: fundamentals and control*". 2nd. Ed., Florianópolis, SC, Brazil.

Griffin, M.J., 1998. "*Handbook of Human Vibration*". London: Elsevier Academic Press, 988p.

ISO 2631-1., 1997. "*Mechanical vibration and shock – Evaluation of human exposure to whole body vibration – Part 1: General requirements*". International Organization for Standardization.

ISO 5349-1., 2001. "*Mechanical vibration – Measurement and evaluation of human exposure to hand-transmitted vibration – Part 1: General requirements*". International Organization for Standardization.

Medeiros, J.B., 2011. "*Efficacy of hearing protection systems to SPL spectra on CORSAN water treatment plants"* Monograph on Occupational Health and Safety, UFRGS, Porto Alegre, RS, Brazil.

NR-15. Regulatory Standard No. 15., 2014. "*Atividades e operações insalubres - Vibrações*". <http://www.mte.gov.br/legislacao/normas_regulamentadoras/nr_15.pdf>, acessed 04 Dec. 2014.

NR-15. Regulatory Standard No. 15., 2014. "*Atividades e operações insalubres - Limites de tolerância para ruído contínuo, intermitente e de impacto"*. <http://www.mte.gov.br/legislacao/normas_regulamentadoras/nr_15.pdf>, acessed 04 Dec. 2014.

Quest-technology, 2005. "*Real-time vibration Analyzers, VI-400PRO"*, Preliminary owner's manual.

Soeiro, N. S., 2011. "*Vibrações e o Corpo Humano: uma avaliação ocupacional*", *Proceedings of 1º Workshop de vibrações e Acústica*. Brazil.

Tosin R.C., 2009. Avaliação do ruído e da vibração no posto de trabalho em dois tratores agrícolas. Tese de Doutorado em Agronomia, UNESP (Botucatu), SP, Brazil.

Trebien, E.V., Machado, M.M. and Sackser R.M., 2010. "*Qualidade de vida no trabalho", Proceedings of 3ª. Jornada de vida no trabalho*. 10p. Brazil.

7. RESPONSIBILITY NOTICE

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