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INFLUENCE OF VISION IN HUMAN COMFORT LEVELS TO WHOLE BODY VIBRATION

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Abstract. *Vibration comfort is very important, since high levels may cause health or even difficulty in accomplishing tasks. Several parameters need to be considered when studying the levels of vibration a human being supports. Among them, one can mention the influence of sex, age, corporeal mass index (CMI), temperature, humor, vision, etc. The first three parameters mentioned were already investigated in previous studies undertaken by GRAVI (Group of Acoustics and Vibration) researchers. In this paper, the influence of vision is evaluated. The main objective of this series of tests performed is to try to quantify in a future the influence of each parameter in a global vibration comfort level. Conclusions are presented for the parameter investigated.*

Keywords: *Human Vibration Comfort, Vision, Perception Threshold, Maximum Acceptable Vibration, Whole-Body Vibration*

1. Introduction

Problems related to vibration stimulus are very frequent in people's life nowadays. Those stimuli may damage health or even disturb the activities that human beings perform. Several factors can be quoted that increase these problems, such as the growth of aerial traffic and the number of heavy vehicles in the cities acting like unpleasant sources of noise and oscillation. The use of metallic structures is another factor that worsen these problems since they are becoming slimmer and lighter, therefore more susceptible to vibration problems than conventional structures due to their low damping levels (Misael, 2001).

Some people feel more the vibration stimuli than others do, since there are several parameters that influence the human beings' responses making them more susceptible than others when submitted to such stimulus. There are books (Griffin, 1996), standards (ISO 2631/1, ISO 2631/2) and papers (Chang, 1973; Fairley and Griffin, 1988; Parson and Griffin, 1988 and Seidel and Heide, 1986) related to whole-body human vibration but none of them study individually the influence of each parameter that may affect the levels obtained. Moreover, the use of international standards may not be appropriate to the Brazilian reality, since our environment is completely different from the places used to obtain the results.

Therefore, since 2001, a series of researches are being carried out by $\text{GRAVI}_{\text{DEMEC-UFMG}}$ researchers (Group of Acoustics and Vibration of the Federal University of Minas Gerais) with the aim of studying the parameters that influence people's response in a more individually way. The study presented here is part of this wider project studying peoples' response to whole-body vibration. The objective here is to verify if vision is an important parameter that affects people's responses.

In previous works, Misael *et al*. (2002) and Misael (2001), thought women were, intuitively, more sensitive to vibration than men, when they looked at the curves obtained. However, when they analyzed the results using the non-parametric test of Mann-Whitney, they concluded that sex does not interfere on the volunteer's responses. In another study, Pereira and Duarte (2004) researched the influence of age and corporeal mass index (CMI) on volunteer's responses. They concluded that age has stronger weight than the corporeal mass index according to the non-parametric test of Mann-Whitney. Elderly people recorded higher acceleration levels than younger people for both analyzed situations (i.e., perception threshold and maximum accepted vibration at dwellings). An explanation for that may be given by the fact that the reaction is reduced with age making people more tolerant to the environment stimuli. Considering the corporeal mass index variable, they concluded statistically that this parameter does not have influence on the responses, since no major differences were found. This fact counteracted what was expected intuitively, since it is known that the adipose tissue has several functions within the organism like thermal isolation and protection against mechanic shocks (Paulino, 1995). So, this paper studies the influence of vision in this same type of study to verify its influence on comfort levels to whole body vibration.

This paper is organized as follows: section 2 presents some human body resonance frequencies. Section 3 describes the methodology applied. Section 4 presents the experimental results and their discussions. Finally, section 5 shows the conclusions drawn in this study.

2. Human Body Resonance Frequency

The human body can be considered as a complex system with several degrees-of-freedom. Moreover, it does not present response linearity when exposed to vibration stimulus. Therefore, when studying the effects of vibration on human beings it is important to consider not only the system response but also the pathologic, physiologic and psychological effects that the vibration energy will produce in the subject (Griffin, 1996).

There are some studies where the body is considered as a single mass and the range of resonance frequencies is found according to the position of the body and the direction of vibration (Chang, 1973; Von Gierke and Brammer, 1998). When internal organs are taken into consideration, completely different results are found. The human body will have different resonance frequencies for its internal organs depending on the direction and position of the person subjected to the vibration stimulus (ISO 2631/1, 1997). Several studies have been undertaken with the objective of obtaining the dynamic response of human organs but, unfortunately, some difficulties were present (Von Gierke and Brammer, 1998). Such difficulties can be attributed to the fact that these studies used animals, dummies or even dead bodies instead of living people. Therefore, the frequencies found through these studies differ slightly from reality but serves as an important reference source. Table 1 presents some resonance frequency values of human body organs collected from the work by Von Gierke and Brammer (1998) and Chang (1973), as presented by Misael (2001).

Table 1. Resonance frequencies of human body organs

Organs	**Resonance Frequencies (Hz)**
Head	20 a 40
Spinal Column	8
Chest Wall	60
Abdominal	4 a 8
Shoulders	4 a 8
Lungs	4 a 8
Hands and arms	20 a 70
Ocular globe	60 a 90
Maxilla	100 a 200

The majority of the values presented in the above table are a range of values due to the inter- and intra-variability inherent to human beings. The first variability states that, the same organ, but in different subjects, have different resonance frequencies. Sometimes, the same organ, in the same subject, can also have different values depending on the circumstances due to the intra-variability of the results. Nevertheless, the frequencies presented in Tab. 1 may be used to interpret results obtained during whole-body vibration studies.

3. Methodology

3.1. Experimental Set-up

The experimental set-up and methodology adopted for the study presented here are the same as that used by Misael (2001). The subjects were sat in a wooden chair having metallic feet. The chair had backrest but no cushion. It was positioned over a metallic plate (660 x 950 x 3 mm) with an approximate area of 0.7 m^2. The position of the chair was such that the gravity center of the set-up (chair + subject) was coincident with the geometric center of the plate. The reason for that is to have the maximum excitation at the vertical direction (z – axis), besides avoiding undesirable rotational movements. The plate was supported by four compression springs with 15 cm of external diameter, 5 cm of wire diameter and 36 cm of height. The responses were measured by a 353B34 PCB accelerometer at the geometric center of the plate. A small magnet shaker (B&K model 4810) was used to provide the sinusoidal excitation generated by an HP 35670A analyzer. A B&K 2706 amplifier provided the amplification of the signal sent to the shaker. Figure 1 shows one view of the experimental set-up employed.

Figure 1. Equipment set-up used

3.2. Sample information

For most of the studies found related to human comfort, the volunteers were gathered from an academic environment. However, care has been taken to prevent the responses to be biased. So, in order to have the sample statistically representative it has to be the most random as possible, including all kind of people, irrespective of race, social class, gender, etc. One way found by Fairley and Griffin (1988) to achieve that was to pay people to take part in their experiments. Due to the low budget of the research presented here, that was not possible. Consequently, it was not easy to find people to take part in the experiments. So, most of the volunteers for this research were selected among the individuals that go to the Mechanical Engineering Department of the Federal University of Minas Gerais every day.

The volunteers were selected after filling out a form about their general health condition as recommended by Griffin (1996). The researchers then gave an explanation about the experiments and another form was filled out, given the volunteers consent. In order to make the research more reliable, the Ethic Committee in Research of the University approved the project first, as that is also a requirement for researches involving human beings.

In this study, the responses from two groups of volunteers are evaluated. Each group is composed by ten subjects and represented the extremes of the parameter in study, i.e., vision. So, the subjects with their covered eyes composed one group and the subjects with uncovered eyes formed the other group. The aim is to verify if vision is an important factor that influences people answers.

The methodology adopted here, as mentioned, is the same as the one developed by Misael (2001) and so, in order to make the results comparable, the same sample size was used, i.e., 20 subjects. That sample size (n) was established according to Eq. (1) (Spiegel and Di Franco, 1997), using a pilot sample taken as 10 subjects when Misael (2001) studied the parameter sex. Eq. (1) is based on the standard deviation (s) and the expected error (E) obtained from the pilot sample. For a 95% confidence interval, $z_{a/2}$ = 1.96.

$$n = \left[\frac{z_{a/2} s}{E} \right]^2 \qquad (1)$$

Another way of determining the sample size is to use the same size from similar experiments. In that way, most of the studies found used a sample size between 08 and 40 subjects. That validates the size sample used.

3.3. Experiment

The experiment described here had the objective to verify the influence of the parameter vision on people’s responses to vibration considering two cases: a) the perception threshold and b) the maximum acceptable limits of vibration at residences. In spite of knowing that the most common human vibration stimulus at residences is due to the resonance frequency of slabs (that occurs normally between 4 and 10 Hz), only frequencies above 10 Hz could be evaluated. Frequencies below that could not be measured due to the limitation of the shaker to the lowest frequency value of 10 Hz. As the standards (ISO 2631/1 and ISO 2631/2) recommends human vibration measurements between 0 to 100 Hz, that validates the other frequencies used. The comparison among the results of each group concerning the analyzed variable was made using the Non Parametric Tests of Mann – Whitney (Spiegel and Di Franco, 1997).

During the test, the subjects were sat in a comfortable posture with their back upright. The adjustment method was used as explained by Griffin (1996). This method consists of asking the subjects to adjust the magnitude of the motion at each tested frequency until it reaches the expected limit. At the beginning of each test session, the amplifier knob was set to the initial position (i.e., position zero). The amplifier was positioned as close as possible to the subjects to prevent interfering with the experiment.

Eight frequency values were used (i. e., 16, 20, 25, 31.5, 40, 50, 63 and 80 Hz) for the sinusoidal vibration at the vertical direction (z-axis). These frequencies corresponded to the center frequency values of the 1/3 octave band within the range from 10 to 100 Hz (due to the shaker limitation mentioned). Each subject responded to the vibration stimulus according to the following conditions:

- Case (A) – the lowest magnitude of vibration a subject could feel (i.e. perception threshold);
- Case (B) – the lowest magnitude of vibration that same person would consider unacceptable if it occurred in his/her residential environment (i.e. maximum vibration acceptable limit at residences).

The subjects first made the adjustment to the perception threshold (case A) and after adjusted to the maximum vibration acceptable limit (case B). When the required level was reached, the signal was recorded and the magnitude written into the test sheet of the volunteer. It is important to say that the frequency values were provided to the volunteers in a random way by the researcher to prevent the responses to be biased.

4. Results

4.1. General Information

During the experiment presented in the previous section, the temperature in the $\text{GRAVI}_{\text{DEMEC-UFMG}}$ (Group of Acoustics and Vibration) laboratory where the tests were carried out was between 22 ºC and 30 ºC. Due to the proximity of this laboratory to the workshop of the Mechanical Engineering Department, noise within the laboratory varied from around 50 dB (when the workshop was not functioning) to 70 dB (when the workshop was in operation). The average time for the whole experiment (including tests and recording of the results) was around 30 minutes. The subjects could move during the recording of the results, however everybody stayed sat on the experimental set-up used, although in a more relaxed position.

4.2. Experimental results

Figure 2 shows the average values obtained for the two studied situations considering the parameter vision (i.e., cases A and B). Analyzing the results, it can be noticed that for the parameter vision the participants were more sensitive in the lowest frequencies. The value of acceleration measured increased with the increase of the frequency (i.e., the sensibility decreased) until reaching a peak between 40Hz and 50Hz and later it decreased again. The results may have been influenced by the resonance frequencies of the head and ocular globe, as shown in Table 1. That same behavior was verified in the analysis of the parameters sex, corporeal mass index (CMI) and age in previous studies (Misael, 2001; Pereira and Duarte, 2004). So, independent of the parameter in study, the studies indicated that the subjects are more sensitive in lower than in upper frequencies, agreeing with the other researchers' results and standard (Parsons and Griffin, 1988; ISO 2631/2, 1989). However, these references do not show a decrease above 50 Hz.

It is important to stress that the experiments were carried out with the subjects seated, as the results can be influenced by the posture, orientation and position of the body when this type of study is made (Parsons and Griffin, 1988). Moreover, the setup used for the test may influence the results obtained, due to amplification at low frequencies or attenuation (at high frequencies) of the vibration stimulus (Freitas Filho, 2003).

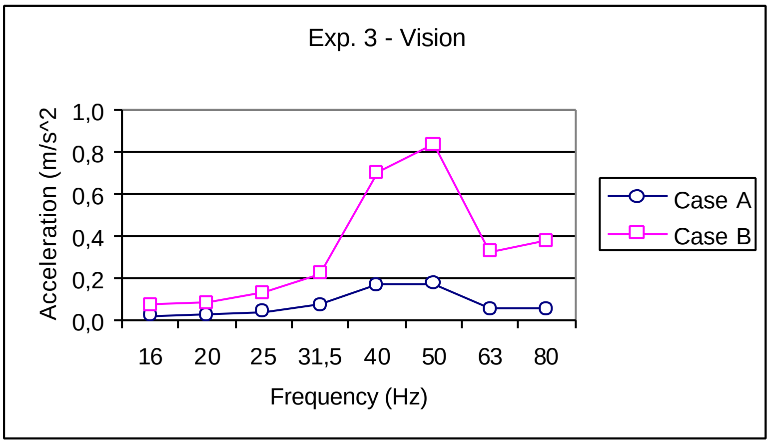

Figure 2. Results of the experiment considering the parameter vision (cases A and B)

Figure 3 presents the relationship B/A between the two test cases studied. The behavior of this curve is similar to that presented by the curves in the norm ISO 2631/2 (1989), in other words, there is an increase of the relationship with the increase of frequency. An important observation should be made again. There is a repeatability difficulty inherent in this type of study, mainly due to the inter- and intra-subjectivity of the subjects (Griffin, 1996).

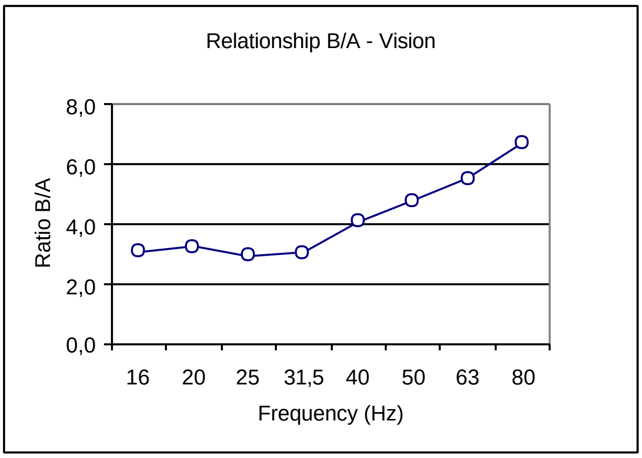

Figure 3. Relationship among the results for cases A and B – parameter Vision

Figure 4 and 5 show the results obtained for case A and case B, respectively, considering the two groups analyzed for the vision parameter (i.e., with covered and uncovered eyes). Visually, it can be noticed by the curves that the volunteers with covered eyes were, in average, slightly more sensitive than the volunteers with the uncovered eyes for most of the frequency values studied, registering small acceleration levels both for cases A and B. The fact of covering the eyes can leave the subjects more concentrated and aware of the vibration effects than for the uncovered eyes, so explaining their answers been smaller than for the uncovered eyes' group. It is worth pointing out here that hearing could be helping them detecting the vibration. New studies shall be made to confirm these hypotheses.

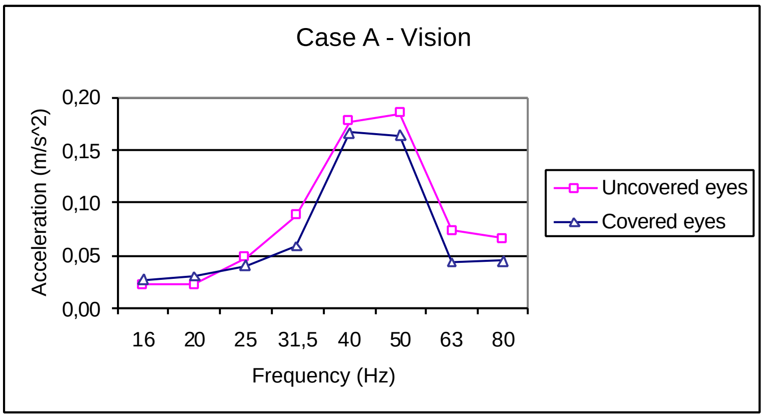

Figure 4. Comparison among the averaged results with covered and uncovered eyes - Case A

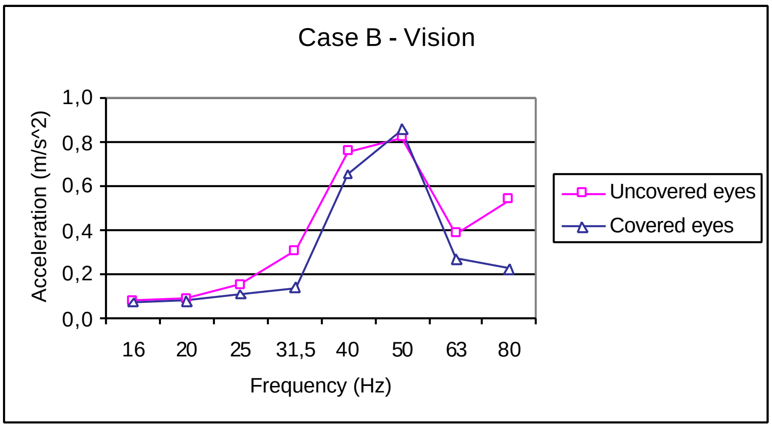

Figure 5. Comparison among the averaged results with covered and uncovered eyes - Case B

Another observation has to be made with respect to the sample used for the vision study. The same volunteers were used in the two groups, however the tests were carried out at different times. This fact may have influenced the results for the second tests, once the subjects were already familiar with the experiments. Moreover, as already mentioned, there is always the subject's intravariability, i.e., the same individual responds differently at different times (Griffin, 1996), according to the circumstances. Figure 6 and Figure 7 present the results' comparison at 31.5 Hz and 80 Hz, respectively, for each one of the volunteers used for the two tested cases, i.e., covered and uncovered eyes to show that. As mentioned, the results were obtained at different times.

Analyzing the figures, it can be noticed that for most of the volunteers there was a decrease in the answers in relation to the first test. New tests shall be accomplished to confirm if it is the vision or the previous knowledge of the test that is causing this result' decrease of most of the volunteers. It is interesting to confirm also if hearing aids the volunteers in detecting the vibration stimulus.

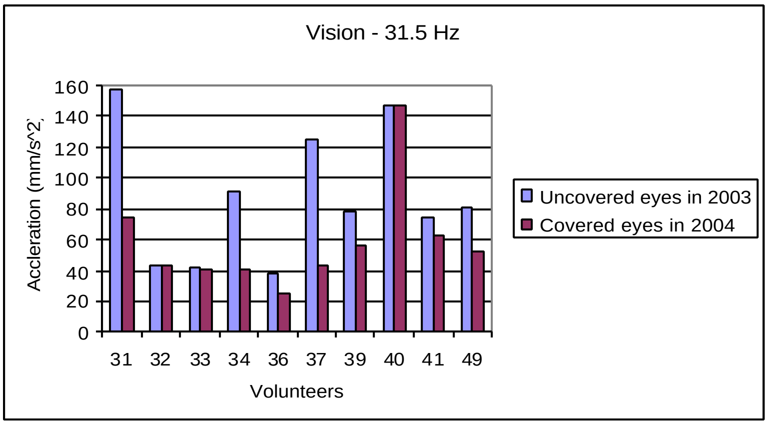

Figure 6. Volunteers' results comparison between each vision situation studied – 31.5 Hz

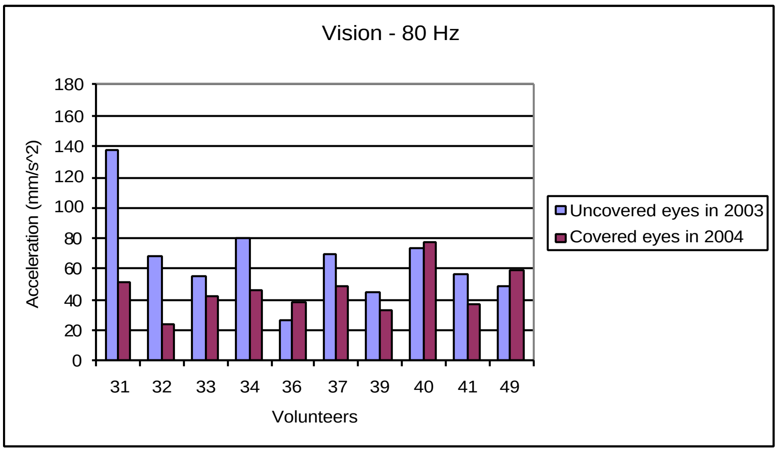

Figure 7. Volunteers' results comparison between each vision situation studied – 80 Hz

A statistical comparison for the vision results was obtained by using the non-parametric tests of Mann-Whitney. Significant differences of 5% were not verified among the volunteers' responses at most of the frequency values considered. Only at 63 Hz, Case A, and at 31.5 Hz and 63 Hz for case B, significant differences were found. This indicates that vision, statistically speaking, is not an important parameter on subject's answers.

5. Conclusions

This work evaluated the influence of the parameter vision in the vibration perception threshold and maximum acceptable vibration limit of subjects when exposed to some vibration at dwellings, such as those using metallic structure. To that end, the answers of two groups of volunteers were compared taking into consideration the extremes of the parameter in study (i.e., covered and uncovered eyes).

The experimental methodology used in this work was the same developed and used by Misael (2001) when studying the sex parameter. All volunteers were submitted to the same frequencies, namely, the center frequencies for the 1/3 octave band in the range from 10 to 100 Hz, due to the low frequency limit of the equipment used. The volunteers made the acceleration amplitudes adjustment, although the frequency presentation was made in a random way by the researcher.

The vision results presented the same curve behavior found in previous studies considering sex, corporeal mass index and age, i.e., the sensibility decreased with the increase of frequency (as acceleration level increased) reaching a minimum between 40Hz and 50Hz and later increased again around 80 Hz. This fact indicates that independently of the parameter in research, the volunteers adjust small acceleration levels for lower frequencies, and high acceleration levels for higher frequencies, although for the series of studies performed there is a decrease in the acceleration levels above 50 Hz again. Despite the same behavior, the values obtained for each parameter was different. Moreover, around 40 and 60 Hz, the results may have been influenced by the resonance frequencies of the head and ocular globe. Also, at low frequencies, the setup used influence the results obtained since there is vibration amplification at that region, making the subjects adjust smaller acceleration levels than at the high frequencies, where isolation occurs.

During the statistical analysis of the variable Vision, no differences were found between the two groups studied. In spite of that, the average of the subjects' results for the covered eyes was smaller than the average of the subjects' results for the uncovered eyes. The fact of covering the eyes can be helping the subjects to be more concentrated, so making possible for them to notice the vibration of smaller intensity. However, the volunteers' results for the covered eyes could have being influenced by previous knowledge of the tests as well, as the same sample that took part previously in other tests were used for the analysis of the uncovered eyes. For most of the participants there was a decrease in the answers. No repeatability analysis was undertaken to confirm this fact. New tests shall be accomplished to confirm these hypotheses.

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