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EVALUATION OF VIBRATION LEVELS IN DRIVERS OF CARGO VEHICLE COMPOSITIONS ON DIFFERENT TRACKS

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Abstract. *The following paper presents an experimental study and data analysis concerning acceleration exposure levels in drivers of Cargo Vehicle compositions. The measurements were taken with a 6x4 truck attached to a bulk-carrier semi-trailer that was loaded during first data collections and empty for the second. The accelerations obtained with these measurements were compared with the limits provided by ISO 2631-1 (1997) standard. Results showed that the vibration levels are within the limits established by ISO 2631 (1997) only in a pavement road with perfect conditions.*

Keywords: *Whole-body vibration (WBV); ISO 2631; Drivers; Cargo Vehicle Compositions (CVC); Accelerations; Truck.*

1. INTRODUCTION

The large global demand for food, electronic products and minerals and the necessity of a faster production flow of these products, resulted in an intensification of the automotive industry in the first decades of the twentieth century, leading to the massive production of trucks and road equipment all around the world. In Brazil, according to data from FENABRAVE, in 2011 were licensed 172.661trucks and 58.577 road equipment. Although every year we have a significant increase of motor vehicles on our roads, the conditions of these roads are not always good. The large number of vehicles on the roads increases deterioration on existing roads and demands for the construction of new ones, which require a large demand of resources. Road deterioration along with a significant increase number of wheeled vehicles on the roads provided an increase number of people exposed to the risks found on the road (vibration, dust, smoke, noise, etc.). The continuous exposure to these agents can cause respiratory diseases, back pain, stress and others. These diseases generate a large economic impact in the country, therefore it is important to search ways to reduce the incidence of these diseases and increase the life quality for people who work daily on Brazilian roads.

Within this context, this research was conducted to verify, in accordance with ISO 2631 (1997) standard, the vibration levels that drivers are exposed to in their work environment. Exposure to whole-body vibration may be a causative agent of lumbago. Recent studies demonstrate the need for searching more information about it. Andrusaites (2004) interviewed 489 male truck drivers, of whom 410 were selected for the study. Besides confirming that 59% of truck drivers had back pain, the author also mentions that among all the variables studied, it can be statistically verify that the risk of a driver developing lumbar pain increases 7% for each hour of work. Another study that also raises this issue was published by Lemos (2009), which conducted a survey with 470 truck drivers connected to a carrier from the state of São Paulo, among the total interviewed, 27.9% complained of pain in the lumbar spine. Another area mentioned is the backbone (26.2% of respondents).

Despite of recent studies, still there is no certainty neither on the quantification of the effects of vibration to which the drivers' body are exposed daily, nor on the influence of the conservation of the road in this vibration level. The damage and discomfort caused by vibration have been studied over the past for the last four decades, being a matter of a great interest.

2. EXPERIMENTAL PROCEDURES

A 6x4 truck were used for the testing, which was coupled with a three axle implement, as shown in Figure 1.

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Figure 1. Truck used for the tests.

The seat of the truck, shown in Figure 1, was instrumented with the following equipment:

- Accelerometers of 10g (positioned on the seat, being a transverse accelerometer and horizontal accelerometer);
- Accelerometer of 5g (positioned on the seat, being a vertical accelerometer);
- Two accelerometers of 25g (positioned on the truck cabin floor and the back of the driver);
- Seat pad;

The instrumentation placement is illustrated in Figures 2 and 3.The measurements in the floor were made in the vertical (Z) direction only. In the region of the back, only the horizontal (X) acceleration was measured, and in the region of the seat, the acceleration was measured in three directions (X, Y, and Z).

Figure 2. Fixing the accelerometer in the region of the floor.

Figure 3. Fixing the accelerometer in the region of the seat and back.

The experiment was conducted in three types of tracks, with two different drivers and with two load conditions in the implement: loaded with 30 tons and empty (unloaded). The testing procedure was repeated three times for each driver and these drivers have the following characteristics:

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Driver 1:
- Age: 41 Years Old;
- Weight: 85 kg;
- Height: 1.70 m

Driver 2:
- Age: 59 Years Old;
- Weight: 98 kg;
- Height: 1,71 m

For the dirt track, the route of the test was performed on a stretch of 10 km in RS 110 towards to San Francisco de Paula, RS, Brazil. The track is shown in Figure 4.

Figure 4. RS 110 dirty track.

Measurements on asphalt were conducted in a distance of 7 km from the roundabout access to San Francisco de Paula, towards to the coast of Rio Grande do Sul. This stretch was selected for the condition of the track and the large flow of freight vehicles in the region, which provides from a good stretch to regular conditions with addiction of dimples on the track (Figure 5).

Figure 5. Conditions of asphalt track in the testing area.

The experiment in parallelepiped was conducted on a track from Jacob Lucchesi St. to Jacob Brunetta St., totalizing a distance of 1.8 km. These streets are located at Cohab suburb in Caxias do Sul, RS, Brazil. This stretch was chosen due to different ground conditions, in other words a great deal of irregularities in this track, and at little traffic on the streets, thus facilitating the testing and mobility of the CVC (cargo vehicular composition). The traffic condition and the type of the track can be seen in Figure 6.

Figure 6. Type of track and street conditions of Jacob Lucchesi St.

The three types of tracks presented in this section describe most types of roads that different CVC run daily.

3. RESULTS AND DISCUSSION

3.1 Comparing the RMS values with ISO 2631 (1997) limits

For the dirt track with loaded vehicular composition, the acceleration value (RMS) found in region of the back is within the exposure level for the 4 to 8 hours period. The values in the seat and the floor are above the exposure limit for this period. These results can be seen on Figure 7.

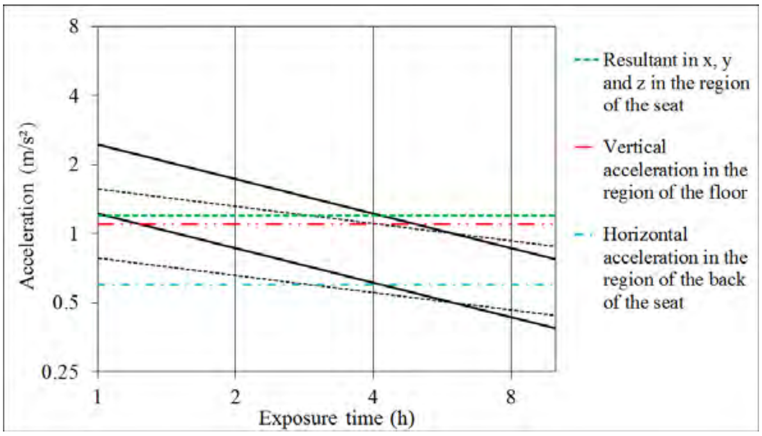

Figure 7. Dirt track.

In the asphalt track with loaded carrier composition, the acceleration values (RMS) found in the back of the driver are below the action level for the 4 to 8 hours period, however, the values in the seat and the floor are above the action level and below the exposure limit for this period, as displayed in Figure 8.

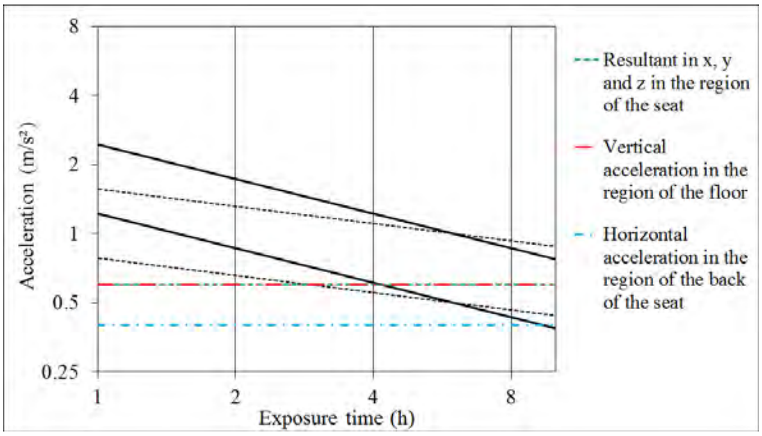

Figure 8. Asphalt track.

Regarding the parallelepiped track with loaded carrier composition, only the acceleration value (RMS) for the back region is below the exposure limit for 4 to 8 hours period. In the region of the floor, the exposure limit value is achieved in approximately 6 hours. On the region of the seat, measurement showed acceleration values above the exposure limit for the range from 4 to 8 hours. These different results can be seen in Figure 9.

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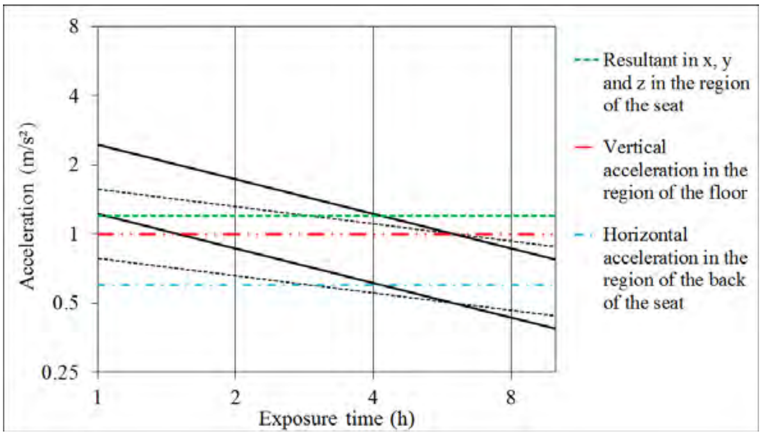

Figure 9. Parallelepiped track.

For the dirt track with unloaded (empty) vehicular composition, only the acceleration value (RMS) for the region of the back, for the driver 1 is below the exposure limit for the 4 to 8 hours period and for the driver 2, the acceleration value was within the limit of 4 hours. The values for the cabin floor area, both for the driver 1 and the driver 2, were within the exposure limit for a period of 4 hours of work and in the region of the seat, the values found were above the exposure limit for the two drivers. These results are presented in Figure 10.

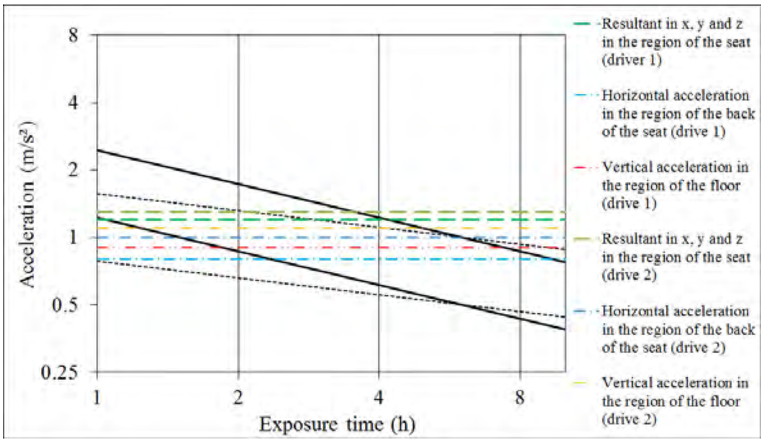

Figure 10. Dirt track.

For the asphalt track with unloaded (empty) vehicular composition, all acceleration values (RMS) are below the exposure limit for the 4 to 8 hours period, as displayed in Figure 11.

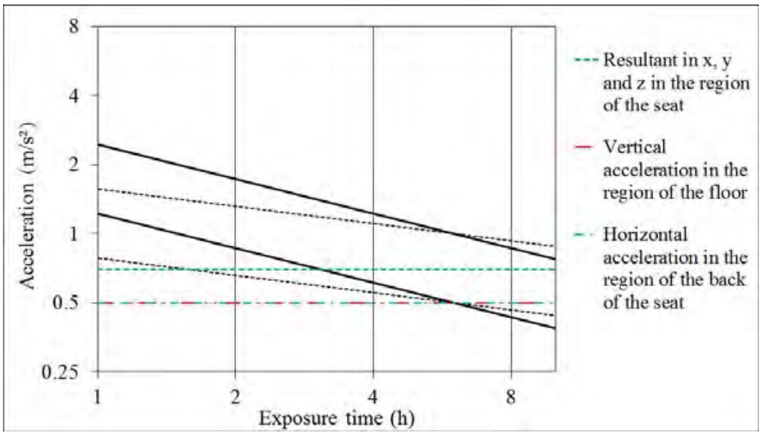

Figure 11. Asphalt track.

For the parallelepiped track with unloaded (empty) vehicular composition, only the acceleration value (RMS) in the region of the floor for the second driver is within of the exposure limit for 4 hours daily. All other results are above the exposure limit for the 4 to 8 hours period. These different results can be seen in Figure 12.

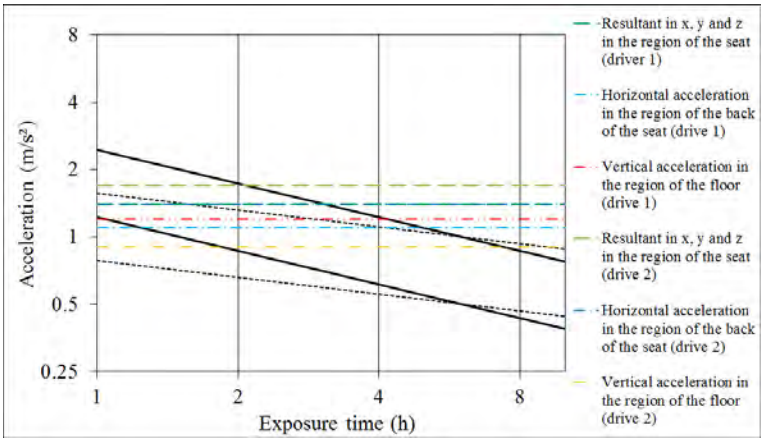

Figure 12. Parallelepiped track.

3.2 Comparison of vibration dose value (VDV)

The VDV values used in this section are from the ISO 2631 (1997) standard and the European Directive (2002/44/EC), and these are:

- ISO 2631 (1997): 8.5 $m.s^{-1,75}$ (action limit) and 17 $m.s^{-1,75}$ (exposure limit);
- European Directive (2002/44/EC): 9.1 $m.s^{-1,75}$ (action limit) and 21 $m.s^{-1,75}$ (exposure limit).

For values found under the stipulated range, there is not enough evidences of injures cause by the exposition to WBV in that condition and the standards do not require an immediate action. For values within the ranges set in the standards there is a need for immediate action to reduce the VDV and exposures conditions above the limits are considered critical cases.

The data were collected at three different tracks, with two drivers for each situation and with the two loading condition, as already mentioned.

For the asphalt track, the resulting values from the tests are under the limit of action for the region of the back and seat as well as the exposure limits for the region of the floor (see Table 1).

Table 1. VDV values resulting from the tests on asphalt track.

	Implement loaded Asphalt track		Implement empty Asphalt track	
VDV	Drive 1	Drive 2	Drive 1	Drive 2
Region of the back	4.7	5.5	6.1	5.6
Region of the seat	7.7	7.6	8.3	8
Region of the floor	10.3	10.1	9.8	9.4

In the dirt track (unpaved), the resulting values of the region of the back and the region of the seat are within the exposure limits of the standards, but with values much higher than those found in asphalt track. For the floor area, all values are above the exposure limit of the standards, as shown in Table 2.

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Table 2. VDV values resulting from the tests on dirt track.

	Implement loaded Dirt track		Implement empty Dirt track	
VDV	Drive 1	Drive 2	Drive 1	Drive 2
Region of the back	7.5	8.5	13	16.6
Region of the seat	11	14	15.6	16.2
Region of the floor	19.8	20.2	19.1	20.5

In the parallelepiped track (paved with stone), only the region of the back is within the limits of exposure of the standards, except for the results obtained with the second driver, which is below the exposure limit of the European Directive. The resulting values for the region of the seat as well as for the floor are above the exposure limits, as shown in Table 3.

Table 3. VDV values resulting from the tests on parallelepiped track.

	Implement loaded Parallelepiped track		Implement empty Parallelepiped track	
VDV	Drive 1	Drive 2	Drive 1	Drive 2
Region of the back	8.3	10.4	16.4	20.7
Region of the seat	20.4	23.8	19.5	20.1
Region of the floor	22.5	25.8	21.5	29.7

4. CONCLUSIONS

The paper presents the results obtained in measurements of accelerations to evaluate the vibration levels to which drivers of vehicular compositions are exposed daily according to ISO 2631 (1997). For comparison purposes, the VDV from the European Directive (2002/44/EC) was also used.

Therefore, accelerations imposed to drivers were measured in different pavement situations, with loaded and unloaded carrier composition and also with two drivers for each test.

Examining the results of all the tracks, it was observed that when the load carrier composition travels in asphalt runway, the acceleration levels are within the exposure limit recommended by ISO 2631 for the 4 to 8 hours period, for both the situations with or without payload and also for both drivers. However, with the change of pavement, the results vary considerably, ranging from acceptable acceleration levels to levels above of the limits present by current versions of referenced standards.

Another important conclusion of the work was that the accelerations values comparing the two drivers have not changed for the condition of loaded composition vehicular cargo. However, for the unloaded composition, there seems to be a driver dependent difference.

Anyway, in general, it can be concluded that the accelerations levels found vary greatly with the imperfections on the track, and only when the tracks are smooth, the accelerations will be within the exposure limit stipulated in ISO 2631 standard, without needing preventive measures.

5. ACKNOWLEDGEMENTS

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7. RESPONSIBILITY NOTICE

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