Use of an Artificial Test Track to Declare Field WBV Tractors Data by Manufacturer

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Abstract

As requested by Directive 2002/44/EC the employer have to declare vibration level exposure of his employees. This is a problem never solved related to the field tractor WBV data declaration.
Also if for the Italian law the employers may use manufacturers' WBV data, it must be clarified that these data are only obtained in laboratory, as requested by standards, to guarantee high repeatability and reproducibility values.
If manufacturers could use a standard WBV measurement criterion to simulate the field operations, it should be sufficient to measure vibration values with this method and then to write them in the machine instructions. In this way the employer can be reassured for the WBV data declaration, which is mandatory by law, but which is difficult to retrieve correctly because it depends on mass and geometry of the vehicle, speed of travel, pressure of the tires, type of ground, performed operational cycle.
In this article the first results of WBV values measured on a agricultural tractor travelling on the artificial test track (ISO 5008) and on the grass are given.

Keywords: WBV, artificial test track

Introduction

It is recognised that tractor operators are exposed at high levels of whole-body vibration (WBV) during field operations as well as during on road and offroad transportation (Bovenzi, 1994). Low-frequency vibrations consequences, produced by the agricultural vehicles, can be extremely severe and mainly depend on the soil type over that the agricultural vehicle is crossing and from its forward speed (Lines et al., 1995, Scarlett et al., 2007).

To analyze vibration transmitted at the seat of the tractor driver, many studies have been carried out both in controlled and standardized situations (Banfo G.L. et al., 1997, Deprez et al., 2005a, 2005b, Paddan and Griffin, 2002, Scarlett et al., 2007). Many of these studies have been done on the basis of the international standard ISO 2631 (1978). A specific standard has been set up for seat laboratory measurements (ISO 5007, 1980) and for measurements on normalised track (ISO 5008, 1979).

As requested by 2002/44/EC Directive, the employer must declare the employees vibration level. To evaluate the vibration risk, the employer may use information given by machine manufacturer, as reported in the machine use and maintenance booklet. In this case, however, he must consider that vibration values refer to test conducted in particular situation (laboratories) and usually these data are lower than others measurable during real machine utilisation. The vibration values as reported in the machine use and maintenance booklets are useful to satisfy the 42/2006/EC Directive requests ("Machine Directive") which establishes that manufacturers must furnish, among many other things, their machine vibration levels before commercialisation. For this reason, machines must be tested using technical standards to guide how and where test the machines. Unfortunately, a specific standard for agricultural tractors does not exist and only generic standards may be used, which do not solve the question of vibration data declaration for employers

Aim of this work is therefore to identify a test methodology which may support the agricultural tractor manufacturers to define their machine vibration level. As a consequence, the employers should receive an effective help to evaluate the vibration risks for themselves and for their operators.

Materials and Method

Tests have been conducted at the CNR IMAMOTER testing facilities, located at Pratofiorito (Candiolo, TO).

Tested tractors

Tested tractors (tab.1) were of A category (78/764/EC Directive), class I (unladen mass < 3600 kg), class II (3600 kg < unladen mass < 6500 kg), class III (unladen mass > 6500 kg).

Table 1: Main characteristics of tested tractors

Tractor	Weight			Tires			
	Front (kg)	*Rear (kg)*	*Total (kg)*	*Front*	*Pressure (atm)*	*Rear*	*Pressure (atm)*
I /A Unsuspended	1190	1550	2740	Trelleborg TM 700 270/70 R16	2	Trelleborg TM 700 420/70 R24	2
I /B Unsuspended	1230	2200	3430	Galaxy 10.00-16	2	Galaxy 18.4-34	1.6
II /C Unsuspended	1670	2410	4080	Pirelli 480/65 R24	1.2	Pirelli 600/65 R34	1.2
II /D Unsuspended	1945	2445	4390	Michelin Multibib 480/65 R24	1.6	Michelin Multibib 540/65 R38	1.6
III /E Suspended front axle & cab	2570	4045	6615	Continental 540/65 R 28	1.6	Continental 650/65 R 38	1.6

They were equipped as originally furnished by manufacturers: ballasts were not added and tires were the manufacturers ones. Concerning tires pressure, machine use and maintenance booklets were referred and lacking information were directly retrieved by tires manufacturers.

Test environment

To verify the proposed methodology applicability, for the moment tests were carried out on the grass and on a artificial track. Therefore, tests on a grass surface at 10 km/h speed, typical of many hay-making operations (especially cut) were conducted. Subsequently tractors passages on a smoother ISO track (ISO 5008) from 1 until 14 km/h speed were observed. Forward speed for each tractor was monitored by a Peiseler wheel. During all the tests, the same drive behaviour was maintained and the same operator (70 kg mass and 180 cm height) was involved.

For each tractor and for each forward speed, both on grass and on artificial track the acceleration values averages were calculated.

Standards

Tests have been carried out following the requests of International Standard ISO 5008 that defines the specification of instruments, measurement procedures, measurement site characteristics and frequency weighting that allow agricultural wheeled tractors and field machinery whole body vibration measurements to be made and reported with an acceptable precision. Vibration have been evaluated in accordance with currently standard (ISO 2631-1) which includes means of weighting the vibration levels at different frequencies to take account of the frequency sensitivity of the human operator to whole body vibration.

Tracks description

For the artificial track tests, vibration measurements have been carried out when the tractor was driven over a 100 m smoother track, that consists of two parallel strips suitably spaced for the wheel track of the tractor. The surface of each strip is formed of pieces of wood sited firmly in a base framework. The surface of each track strip has been defined by the ordinates of elevation, with respect to a level base, listed in tables of ISO 5008.

Instead, the grass track was a normalised one, present at the IMAMOTER experimental field site, with an homogeneous grass cover.

Instruments

For the acceleration data acquisition a three channel analyzer was used, to obtain at the same time the three axis (X, Y and Z) measurement. The used measurement system also let to execute the frequency analysis in the 0.5-80 Hz band (these range is interesting at hygienist level for the whole body vibration exposition, as reported inside the ISO 2631). A tri-axial accelerometer ICP® (Integrate Current Preamplifier) was put on the cab floor (platform), in the vibration transmission point to the seat. As the tractor seat was new of factory, in order to avoid any effect of the seat running in, the measurements of vibration were executed only on cab floor.

Instruments

For these tests, only the z-axis (cranium-caudal) analysis was performed, because this is the more solicited axis respect the others (x: back-ventral and y: lateral). Moreover to the z-axis the weighing Wk curve for the whole body, as requested by ISO 2631, was applied.

Therefore, all the acceleration values were analyzed by a 1/3 octave band spectrum analyzer.

Acquisition times were of some minutes for grass track tests, whereas for the smooth ISO track tests times were bind to the machine forward speed (from 59 seconds for the 6 km/h forward speed, until 25 seconds for the 14 km/h forward speed).

At least three repetitions for each velocity were executed.

Results

A first analysis of the acquired data on the grass track reveals that, in many cases, the main frequencies interest the frequency lying between 2 and 6.3 Hz.

Therefore the equivalent acceleration averages of the passages over the grass track and over the artificial track, for each speed, have been compared. Independently from the tractor class, the artificial track speed which generates more similar values (both as equivalent acceleration value and spectral distribution) to the same obtained over the grass track is 4.5 km/h, as reported in the graphs of figures 1, 2, 3 and 4.

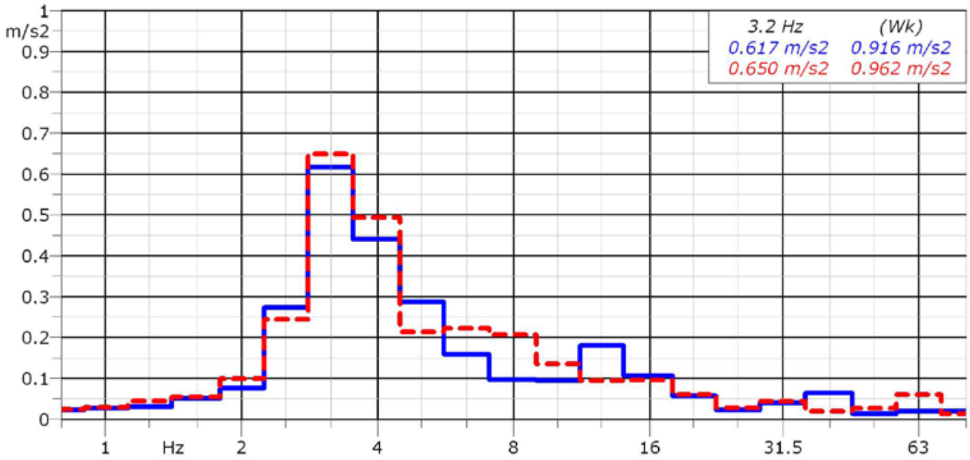

Figure 1. Acceleration value averages for frequency band of tractor A (class I, mass 2870 kg) on grass (10 km/h, blue line) and on smooth track (4,5 km/h, red dot line)

From the figure 1 graph it is evident that solicitation distributions over the tractor cab floor generated by grass path mainly occur in the frequency field from 2.5 to 5 Hz. Some resonances are observable at higher frequencies, but they are less representative than the global value.

An interesting result is obtained crossing the smooth track at 4.5 km/h: the energy distribution transmitted to the cab floor of the tractor is quite similar to the one obtained from the grass track passages at 10 km/h. As reported in the values of the graph in figure 1, acceleration values, frequency weighted (Wk), over the vertical direction z, are quite the same and differ only of a 5% (0.916 and 0.962 m/s^2).

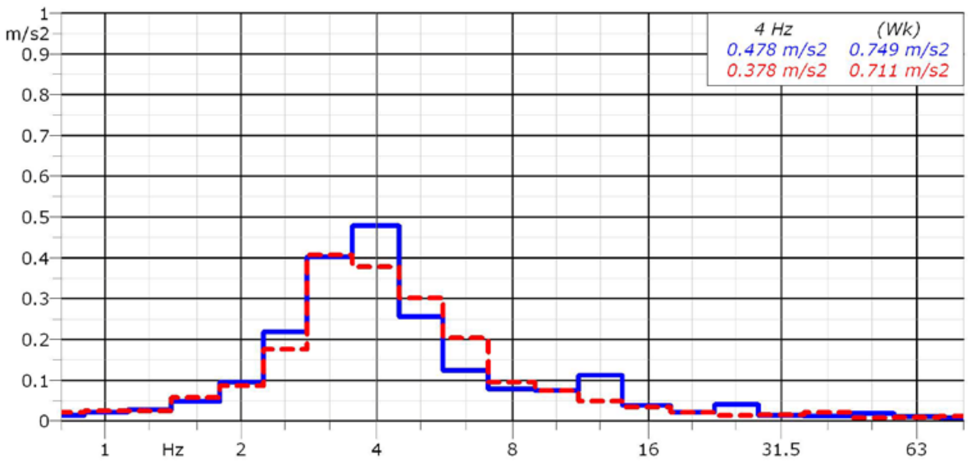

Figure 2. Acceleration value averages for frequency band of tractor B (class I, mass 3430 kg) on grass (10 km/h, blue line) and on smooth track (4,5 km/h, red dot line)

Also in the case represented by the figure 2 graph, the most relevant spectrum distribution is always included in 2.5 – 5 Hz interval, but with the average peak of the grass cross shifted to 4 Hz. Likewise at the previous case, the frequency weighted acceleration values are similar (0.749 and 0.711 m/s^2).

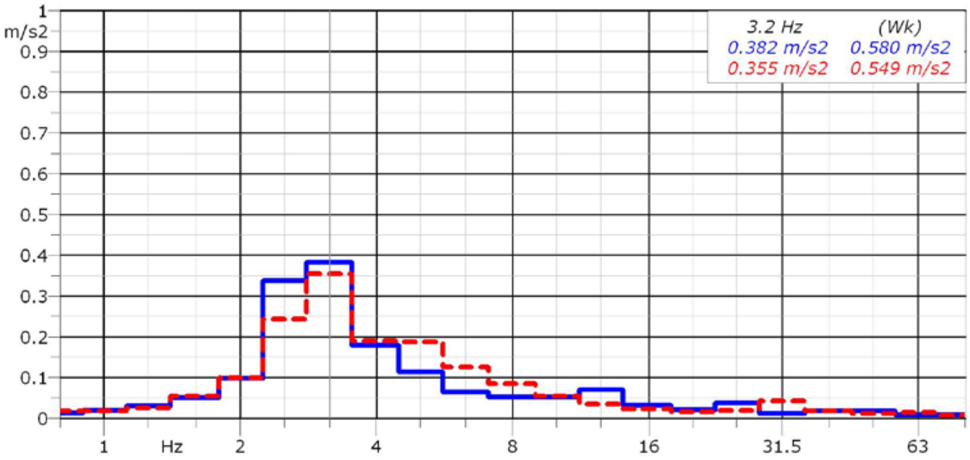

Figure 3. Acceleration value averages for frequency band of tractor C (class II, mass 4080 kg) on grass (10 km/h, blue line) and on smooth track (4,5 km/h, red dot line)

It is evident, observing the graph in figure 3, that for the class II tractor C the cross on grass track produces an highest relevance of frequency distribution shifted to lowest frequencies with respect to 4 Hz with a dominance in the range 2.5-3.2 Hz. Frequency values are equally well represented in the case of passage on artificial track. Also acceleration equivalent values are very similar (0.580 and 0.549 m/s^2).

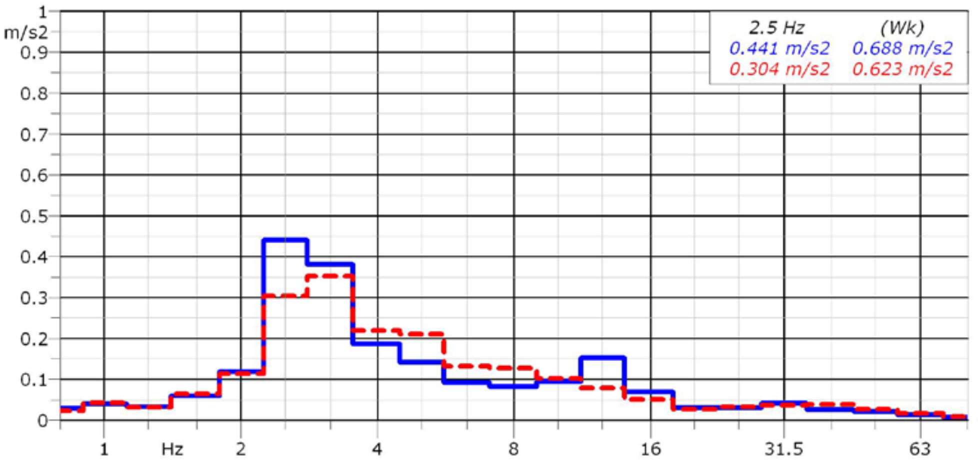

Figure 4. Acceleration value averages for frequency band of tractor D (class II, mass 4390 kg) on grass (10 km/h, blue line) and on smooth track (4,5 km/h, red dot line)

Analyzing the second tractor of class II, there is a frequency distribution centered on frequencies between 2.5 and 4 Hz (figure 4). The passage on the smooth track shows a spectral distribution similar to the graph of figure 3, with a reversal of the levels at frequencies of 2.5 and 3.2 Hz (blue line).

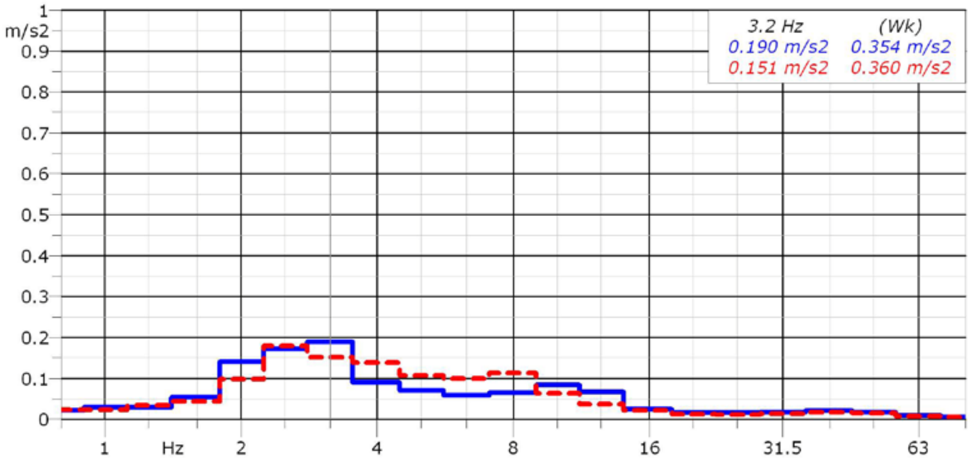

Figure 5. Acceleration value averages for frequency band of tractor E (class III, mass 6150 kg) on grass (10 km/h, blue line) and on smooth track (4,5 km/h, red dot line)

When the tractor mass augments, it emerges (case of graph in figure 4) a most significant frequency concentration toward lowest frequencies, between 2 and 3.2 Hz. The comparison between the spectrum generated by the crosses on grass and the same obtained from the passages on the smooth track let to appreciate a slightly different distribution compared with the previous graphs, also in the frequency range 4-8 Hz. Also in this case measured acceleration values are similar (0.354 and 0.360 m/s^2).

Comparing the graphs of the 4 figures, we can see how the tractor mass increment contributes in a significant way to the realization of a spectrum with lowest acceleration values, more uniformly distributed in the frequency field from 2 to 4 Hz.

The average RMS acceleration values for the 5 measured tractors on the 2 tracks with their percentage difference are referred in table 2.

Table 2 - Acceleration mean values on tractor cab floor

	Grass track Aweq (m/s^2)	Smooth ISO track Aweq (m/s^2)	Mean value difference (%)
Tractor A (class I)	0.916	0.962	5%
Tractor B (class I)	0.749	0.711	5%
Tractor C	0.580	0.549	5%

(class II)			
Tractor D (class II)	0.688	0.623	9%
Tractor E (class III)	0.354	0.360	2%

In conclusion, average RMS acceleration values obtained from grass and ISO track crosses are very similar for each tractor, with highest differences for the tractor D. Moreover, as it was foreseeable, higher masses lead to lowest acceleration values.

Conclusions

Measurement and comparison of vibration levels obtained in each test were not aims of this work: on the contrary, the purpose was to begin to study a simplified methodology for the tractor manufacturers’ vibration levels declaration. Also considering the difficulties met attempting to simplify a complex problem like this, the first results obtained in this work with a first comparison of 5 different tractors running on grass and smooth ISO track are hopeful. Average RMS acceleration recorded are not only similar in all the situations, but even 1/3 frequencies band are overlapping with negligible differences, considering the tire reaction over different roughness surfaces (Deboli et al., 2008).

For example, to declare vibration values of a tractor that must work for hay-making operations, a manufacturer should simply let the tractor travel on a smooth ISO track at the forward speed of 4.5 km/h to obtain a reliable data.

References

Banfo G.L., R. Deboli, G. Miccoli. 1997. Vibration active control device application to earth-moving machines seats. Proceedings of 7th European ISTVS. Ferrara, October 8-10, 1997, 462-469

Bovenzi M. 1994. Low-back disorders in agricultural tractor drivers exposed to whole-body vibration and postural stress. Applied Ergonomics, 25(4), 231-241

Deboli R., A. Calvo A, C. Preti, G. Paletto. 2008. Whole body vibration (WBV) transmitted to the operator by tractors equipped with radial tires. Proceedings of the International Conference: Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-food Systems. September 15-17, Ragusa (Italy), CD

Deprez K., D. Moshou. H. Ramon. 2005a. Comfort improvement of a non-linear suspension using global optimization and in situ measurements. Journal of Sound and Vibration, 284, 1003–1014

Deprez K., D. Moshou, J. Anthonis, J.D. Baerdemaeker, H. Ramon. 2005b. Improvement of vibrational comfort by passive and semi-active cabin suspensions. Computers and Electronics in Agriculture, 49, 431–440

EEC 2002/44. Council Directive on the Minimum Health and Safety Requirements Regarding the Exposure of Workers to the Risks Arising from Physical Agents (Vibration) (2002/44/EC). Journal of the European Communities No. OJ L 177, 6th July, 13pp

ISO 2631. 1978. Guide for the evaluation of human exposure to whole-body vibration. International Organisation for Standardisation, Geneva, Switzerland

ISO 5007. 1980. Agricultural wheeled tractors. Operator seat. Measurement of transmitted vibration. International Organisation for Standardisation, Geneva, Switzerland

ISO 5008. 1979. Agricultural wheeled tractors and field machinery. Measurement of whole-body vibration of the operator. International Organisation for Standardisation, Geneva, Switzerland

Lines J.A., M. Stiles, R.T. Whyte. 1995. Whole body vibration during tractor driving. Journal Low Freq Noise Vib, 14(2), 87–104

Paddan G.S., M.J. Griffin. 2002. Effect of Seating on Exposures to Whole-Body Vibration in Vehicles. Journal of Sound and Vibration, 253(1), 215-241

Scarlett A.J., J.S. Price, R.M. Stayner. 2007. Whole-body vibration: Evaluation of emission and exposure levels arising from agricultural tractors. Journal of Terramechanics, 44, 65–73