Risk exposure to vibration and noise in the use of tracklaying tractors

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Abstract

Human exposure to mechanical vibration may represent a significant risk factor for exposed workers in the agricultural sector, with particular reference to the operators driving tractors. Also noise in agriculture is one of the risk factors to be taken into account for the evaluation of workers health and safety. In particular, one of the major sources of discomfort for the workers operating a tractor is the noise to which they are subjected during work. In Italy, Law Decree 81/2008 has defined the obligations of vibration and noise assessment and risk management. The aim of this study is to evaluate the risk of exposure to whole-body vibration for the operator driving a tracklaying tractor working in vineyard orchard and the noise level close to the ear of the operator driving the tractor. The experimental tests were performed using six different tracklaying tractors, 40-51 kW power, coupled with the same rototilling machine model BF160 by Celli (Forlì, Italy). For the evaluation of whole-body vibration we referred to ISO 2631-1:2008 standard. The tests for noise evaluation were performed in compliance with the standards ISO 9612 and ISO 9432. During the tests we used the portable vibration analyzer HD2070 by Delta OHM, Italy, that is able to perform spectral analysis and statistics simultaneously on three channels, and a precision integrating portable sound level meter, class 1, model HD2110L by Delta OHM, Italy. The mean square frequency-weighted acceleration was evaluated along each of the three axial components of the acceleration vector \(a_{wx}, a_{wy}, a_{wz}\) and the total vibration value. The sound level meter measured A-weighted time-averaged sound pressure level \(L_{Aeq}\) and C-weighted peak sound pressure level \(L_{C\text{pk}}\). This study allowed us to point out that in the use of tracklaying tractors coupled to a rototilling machine, the vibration values referred to the 8-hour working day were always higher than 0.5 m s\(^{-2}\) and, therefore, included in the "risk threshold" identified by Italian Law Decree 81/2008. With reference to noise assessment, the daily noise exposure levels obtained by rototilling always overcome the exposure limit value of 87 dB(A) according to the above mentioned law.

Keywords: safety, tractor, whole body vibration

1 Introduction

Human exposure to mechanical vibration may represent a significant risk factor for exposed workers in the agricultural sector, with particular reference to the operators driving tractors (Lines et al., 1995; Matthews, 1966, Pessina et al., 2012, Scarlett et al., 2007). The growing relevance of this risk in Europe and in the industrialized countries, both in terms health risk, and in terms of economic damage, led to the drafting of regulations and specific measures to reduce it. Directive 2002/44/EC of 25 June 2002 "on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration)" is the key step to ensure the implementation of specific protection measures for the preven-
tion of risk exposure to vibration in the workplace. This study would be a useful tool for users of machines and equipment that may result in exposure to vibrations and noise risk within the agricultural sector in order to be in line with the provisions of the regulations on safety in the workplace. The aim of the research was to assess the risk of exposure to whole-body vibration and noise for the operator driving a tracklaying tractor during rototilling operations in the vineyard.

2 Materials and methods

Farms and experimental tests

The tests were carried out in three farms respectively located in Sicily, south Italy, in the province of Trapani (test site A), Agrigento (test site B) and Palermo (test site C) in vineyard plots.

Test site A

Test site A is located in the province of Trapani 150 m above the sea level. Soil characteristics are referred to lithosols (Lithic Rhodoxeralfs). Texture is sandy loam, no skeleton.

Test site B

Test site B is located in the province of Agrigento 180 m above the sea level. The soil characteristics are attributable to Regosuoli (Tipic Xerorthents). Texture is clayey, the skeleton is absent.

Test site C

Test site C is located in the province of Palermo 280 m above the sea level. The soil characteristics are attributable to Vertisols (Vertic Xerorthents). Texture is clay, the skeleton is absent.

Six homogeneous plots of vineyard in flat, about 200 m long, were identified in the three test sites in order to test six different tracklaying tractors coupled to the same rototilling machine. The aim was to evaluate Whole Body Vibrations (WBV) for the operator driving the tractors during field operations in vineyard and the noise level that comes close to the ear of the operator driving the tractor.

Machines used in the tests

The tractors used during the tests come from different manufacturers, in particular New Holland, Lamborghini and Landini and have different age.

Table 1 shows the main technical characteristics of the tractors used in the tests.

Instruments used during the tests

For vibration measurements, a triaxial piezoelectric accelerometer, a signal conditioner, a digital archiving system, a frequency analyzer, connecting cables and a calibrator were used. The tests were performed according to ISO 2631–1, 2008. It defines standardized methods of measuring whole body vibration and provides some guidelines for the assessment of health effects. The frequency spectrum and the direction and intensity of the acceleration were taken into account for the assessment of exposure to whole-body vibration.
ISO 2631–1: 2008 regulation defines the coordinate systems for accelerations measurement according to the entry point of the vibrations while keeping the axes x, y and z always in the same direction but with different origin according to the operator's position. In whole-body vibration the z (vertical) axis is directed in the direction of the spinal column so this direction is the most dangerous for the drivers. Acceleration levels were measured as frequency-weighted root mean square values, in the frequency range 0.5 - 80 Hz. The measurements were made by inserting the triaxial accelerometer between the seat and the operator (Fig. 2). The accelerations (aw) detected on the x and y axes were further weighted by a factor of 1.4. During the tests we used the portable vibration analyzer HD2070 by Delta Ohm, Italy (Fig. 2). It is able to perform spectral analysis and statistics simultaneously on three channels.

The mean square frequency-weighted acceleration [m s\(^{-2}\)] was evaluated along each of the three axial components of the acceleration vector (awx, awy, awz):

\[
a_w = \left[ \frac{1}{T} \int_0^T a_w^2(t) \, dt \right]^{1/2}
\]  

(1)

The total vibration value to which the body is exposed (aw) was determined by the following relationship:

\[
a_w = (k_x a_{wx}^2 + k_y a_{wy}^2 + k_z a_{wz}^2)^{1/2}
\]  

(2)

where \( k_x = k_y = 1.4 \) and \( k_z = 1 \).

Acceleration data were correlated with the actual time of exposure in order to calculate the vibration risk assessment.

The instrument used in the tests is a precision integrating portable sound level meter by Delta OHM, Italy, model HD2110L. The instrument complies with class 1 specifications of IEC 61672-1, IEC 60651 and IEC 60804 and is able to perform all the measurements required by Italian legislation on the protection of workers from the risk of noise exposure (Law Decree 81/2008 and UNI9432 standard). The constant percentage bandwidth filters are compliant with class 0 IEC 61260 specifications and the microphone with IEC 61094-4. The tests were carried out in compliance with ISO 9612 and ISO 9432 standards.

During the measurements the microphone was placed near the worker's ear at a distance of at least 0.1 m from the entrance of the external ear canal, approximately 0.04 m above the shoulder. Each measurement had a duration of 2 minutes (the case of stationary noise source) and the parameters were analyzed at intervals of 0.5 seconds.

We measured A-weighted time-averaged sound pressure level (LAeq) and C-weighted peak sound pressure level (LCpk).

As required by article 189 of Italian Law Decree 81/2008, the worker does not have to be exposed to \( L_{Ex,8h} \) values (occupational noise) reported to 8 working hours higher than 80 dB(A) and to LCpk exceeding 135 dB(C). Before each series of measurements the instrument calibration was performed applying a sound calibrator. The collected data were downloaded to the PC for processing.

The tests were carried out in triplicates. Analysis of variance and Tukey's test were performed using Statgraphics Centurion by Statpoint inc., USA.

3 Results and discussion

Whole Body Vibration measurements

Test site A

In test site A texture is sandy loam, tractors coupled to the rototilling machine gave frequency weighted vibration levels in the Z-axis between 0.63 and 0.97 m/s\(^2\) (Fig. 3). The highest Aeq value is obtained on the Z axis for all the machines with respect to X and Y axes (Fig. 3). In particular, tractors gave increasing values as the number of worked hours. The older age tractors, T5 (2004) and T6 (2002), reported WBV values higher by about 34% than the younger ones. Regarding the A(8) daily values, calculated considering an effective duration of 7 hours, note that all the tractors overcome the limit action value of 0.5 m/s\(^2\).

Test site B
In test site B texture is clayey, tractors coupled to the rototilling machine gave frequency weighted vibration levels in the Z-axis between 0.73 and 1.05 m/s² (Fig. 4). The highest Aeq value is obtained on the Z axis for all the machines with respect to X and Y axes (Fig. 4). Tractors gave increasing values as the number of worked hours as obtained in test site A. The older age tractors, T4 (2006), T5 (2004) and T6 (2002), reported WBV values higher by about 30% than the younger one (T1, year 2012). Regarding the A(8) daily values, note that all the tractors overcome the limit action value of 0.5 m/s².

**Test site C**

In test site C texture is clay, tractors coupled to the rototilling machine gave frequency weighted vibration levels in the Z-axis between 0.85 and 1.15 m/s² (Fig. 5). As in the previous cases, the highest Aeq value is obtained on the Z axis for all the machines with respect to X and Y axes (Fig. 5). Tractors gave increasing values as the number of worked hours as above. The older age tractors, T4 (2006), T5 (2004) and T6 (2002), reported WBV values respectively higher by about 12, 14 and 26% than the younger one (T1, year 2012). Regarding the A(8) daily values, note that all the tractors overcome the limit action value of 0.5 m/s².

**Noise level measurements**

A-weighted time-averaged sound pressure levels (LAeq) in test sites A, B and C are shown in figure 6 for the six tractors.

Noise pressure values show a minimum of 90.3 dB(A) obtained by tractor T1 in test site A and a maximum of 99.2 dB(A) for tractor T6 in test site C. Figure 6 shows that the upper action value of 85 dB(A), the lower action value (equal to 80 dB(A)) and the exposure limit value (equal to 87 dB(A)) established by the article 189 of Italian Law Decree 81/2008 are always exceeded. Statistical analysis (p < 0.05) shows significant differences between all the test sites for every tractor. Note that as vibration level increases noise level increases too.

With reference to C-weighted peak sound pressure levels (LCpk), neither the exposure limit value equal to 140 dB(C) according to the cited art. 189 of Law Decree 81/2008, or the upper and lower action values (equal to 137 dB(C) and 135 dB(C)) are reached or exceeded by any of the tested machines (data not shown).

4 **Conclusions**

This study was carried out in order to assess the whole body vibration and noise levels transmitted to the operator driving a tracklaying tractor during rototilling operations in the vineyard. The experimental tests were performed in three test site different for soil texture. The younger tractors always gave WBV values always lower than the older ones in the three test sites. The study revealed that soil texture influences the transmission of vibrations to the operator through the driver’s seat. The lighter soils with sandy loam texture (site A) and clayey (site B) gave WBV values always lower than site C that was clayey.

As regards noise risk, the exposure limit value (equal to 87 dB(A)) established by the Italian Law Decree 81/2008 is always exceeded. Moreover, noise values obtained in all the tests show an increase with the increase of the vibrations transmitted to the seat of the tractor. The results obtained from this study do reflect on the use of tracklaying tractors in agricultural farms. After a few years of purchase (from 2 to 4 years), with only 3000 hours of work, WBV values exceed the limit action value (0.5 m/s²).
Acknowledgements

This study was supported by Regional Department of Agricultural and Food Resources within the project “Applicazione di linee guida per la sicurezza sul lavoro e la salute dell’operatore nel settore agricolo in Sicilia”. The authors are grateful to Mr. Salvatore Amoroso for supporting the execution of the tests.

5 References


Figure 1: Rototilling machine coupled with the six tractors used during the tests.
Figure 2: Triaxial accelerometer with adapter for the driving seat to measure whole-body vibrations and HD2070 vibrometer by Delta Ohm, Italy.
Figure 3: Frequency weighted vibration levels: a) on x, y and z axes; b) global weighted acceleration; c) daily vibration exposure value $A(8)$ measured on the driver’s seat of the tracklying tractors in test site A.
Figure 4: Frequency weighted vibration levels: a) on x, y and z axes; b) global weighted acceleration; c) daily vibration exposure value $A(8)$ measured on the driver's seat of the tracklaying tractors in test site B.
Figure 5: Frequency weighted vibration levels: a) on x, y and z axes; b) global weighted acceleration; c) daily vibration exposure value A(8) measured on the driver’s seat of the tracklying tractors in test site C.

Figure 6: Noise pressure level in test sites A, B and C (data are reported as means ± standard deviations of the three replicates).

Table 1: Main technical characteristics of the tractors used in the tests.

<table>
<thead>
<tr>
<th>Tractor</th>
<th>Year</th>
<th>Manufacturer</th>
<th>Mass [kg]</th>
<th>Power [kW]</th>
<th>Wheel track [mm]</th>
<th>Seat b1 b2 h [cm]</th>
<th>Hours of work [h]</th>
</tr>
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<tbody>
<tr>
<td>T1</td>
<td>2012</td>
<td>New Holland</td>
<td>3800</td>
<td>58</td>
<td>1650</td>
<td>40x41x39</td>
<td>2000</td>
</tr>
<tr>
<td>T2</td>
<td>2010</td>
<td>Lamborghini</td>
<td>3750</td>
<td>58</td>
<td>1650</td>
<td>40x41x39</td>
<td>3000</td>
</tr>
<tr>
<td>T3</td>
<td>2008</td>
<td>New Holland</td>
<td>3800</td>
<td>58</td>
<td>1650</td>
<td>40x41x39</td>
<td>4000</td>
</tr>
<tr>
<td>T4</td>
<td>2006</td>
<td>Landini</td>
<td>3780</td>
<td>58</td>
<td>1650</td>
<td>40x41x39</td>
<td>5000</td>
</tr>
<tr>
<td>T5</td>
<td>2004</td>
<td>New Holland</td>
<td>3800</td>
<td>58</td>
<td>1650</td>
<td>40x41x39</td>
<td>6000</td>
</tr>
<tr>
<td>T6</td>
<td>2002</td>
<td>New Holland</td>
<td>3800</td>
<td>58</td>
<td>1650</td>
<td>40x41x39</td>
<td>7500</td>
</tr>
</tbody>
</table>

Table 2: Main technical characteristics of the rototilling used in the tests.

<table>
<thead>
<tr>
<th>Machine</th>
<th>Mass [kg]</th>
<th>Width [m]</th>
<th>Length [m]</th>
<th>Tillage depth [m]</th>
<th>Working tools [n]</th>
</tr>
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<tr>
<td>Rototilling</td>
<td>450</td>
<td>1.80</td>
<td>0.5</td>
<td>0.12</td>
<td>36</td>
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