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ScienceDirect

Journal of Terramechanics 63 (2016) 23–32

Journal of Terramechanics

www.elsevier.com/locate/jterra

Development of a simplified method for evaluating agricultural tractor's operator whole body vibration

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Received 10 April 2015; received in revised form 2 September 2015; accepted 14 November 2015
Available online 9 December 2015

Abstract

Whole body vibrations (WBV) are one of the risk factors causing the onset of professional diseases in agricultural tractors operators: a method for assessing vehicle's properties in terms of vibrations turns out to be fundamental for comfort and safety improvement. Studying agricultural tractor operator exposure to vibrations has always been difficult for the several topics to the tractor is used. Studies have pointed out that the combination of vehicle speed and surface roughness induces a transformation of part of vehicle forwarding speed in vertical accelerations acting as a series of impulses exciting the elastic parts of the tractor to have similar shapes in the frequency domain. Following this consideration the CREA-ING has developed three simplified test track, one for each axis of solicitation, for investigating the possibility of defining tractor's comfort level with a simplified test.

Keywords: Safety; Occupational diseases; Soil profile; PLS; VIP scores

1. Introduction

Occupational diseases result from prolonged exposure to risk factors during work-related activities with respect to the environment, the used equipment, the posture at work, as well as to physical and chemical agents operators are exposed to and represent an extremely important cost under the human and socio-economic point of view (Hoy et al., 2010; Litchfield, 1999).

The World Health Organization (WHO) included five occupational risk factors in its comparative risk assessment, the included outcomes were those for which WHO had rates of disease or injury for all regions calculated by International Classification of Disease (ICD) codes providing risks for injuries, carcinogens, airborne particulates, ergonomic risks for back pain, and noise (Ezzati et al., 2002; Jamison et al., 2006). Occupational exposure has been accounted for 16 percent of all hearing loss, 13 percent of all chronic obstructive pulmonary diseases and of the 37 percent of all back pain worldwide. It was pointed out that vibrations whose frequency is lower than 2 Hz can induce minor and temporary effects like carsickness that, producing remarkable discomfort, interfere with the desired working performance; on the other, long-term exposure to vibrations ranging from 2 to 20 Hz can cause severe diseases, like spinal column degenerative pathologies (Chiang and Liang, 2006; Okunribido et al., 2006; Seidel and Heide, 1986). In 2002 the European Parliament issued the 2002/44/EEC Directive (2002) to set the minimum requirements to protect workers from health and safety risks coming from exposure to mechanical vibrations.

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http://dx.doi.org/10.1016/j.jterra.2015.11.001
0022-4898/

Within this framework, mechanical vibrations, and whole body vibrations in particular, play an important role because, at varying of their intensity, duration and frequency, they can affect agricultural operators health, in particular when driving tractors in ordinarily conditions. During a survey on 1155 tractor drivers, tractor vibration and/or incorrect posture in driving activities caused more than 80% of interviewed to suffer from low back disorders (Bovenzi and Betta, 1994) and confirm that ergonomic aspects in agriculture need adequate attention (Bishu et al., 1989). Monitoring the exposition is particularly difficult for agricultural tractors because of the heterogeneity of environment and working situations that makes not possible to foresee and standardize the operator exposure to vibration. The European legislation requires, actually, to declare the value of homologation of the seat, but the employer has to evaluate the risk of employees as well. The approach is to measure some situation that could be representative of the job or to refer to existing database with similar tractor and use. This approach is technically correct and recognized from the Authority but doesn't solve the problem of evaluating a tractor from a comfort point of view. Regarding the source of vibrations transmitted to the driver, terrain irregularity and forward speed are the most important factors (Deboli et al., 2012; Nguyen and Inaba, 2011; Scarlett et al., 2007) and affect work quality (Bisaglia et al., 2006) with subsequent minor effectiveness and productivity. Agricultural tractors tires have been for several years the main mechanical vibration mitigation device relying, for their effectiveness, on eccentricity, load, resonance frequency, elasticity characteristics and most of the studies have been focused on tires' properties and dumping systems as well as their interaction (Cutini et al., 2012; Ferhadbegovic et al., 2006; Pacejka, 2010; Taylor et al., 2000). For this reason, many research activities have been carried out in order to develop effective devices to mitigate vibration transmission to the drivers (Shaha et al., 2014). Studies have showed that the combination of forward speed with surface unevenness induces vehicle vertical acceleration, due to increasing in normal slope, height, curvature and length (Jianmin et al., 2001; Pacejka, 2010; Park et al., 2004; Wong, 2008). This dynamic has been confirmed also for agricultural tractor with the consequence that vertical acceleration excites tractor elastic components (*i.e.*, tires, cab, rubber mountings, etc.) whose properties determine vehicle dynamics in terms of frequency (Cutini et al., 2010; Cutini and Bisaglia, 2014). The interpretation requires considering the solicitation of the elastic part of the vehicle undergoes following the change in tire rolling radius when passing over a cleat.

Consequence of this is that is possible to suppose that a few range of frequencies is important for operator comfort. Aim of this study is to develop a simplified standard test for defining tractor's vibration comfort properties. This will not allow to foresee the exposure values in a specific working situation but to compare different technical solution. The result is the development of three special test track, one for each axis of solicitation (x, y, z) especially manufactured and presented in this work and compared with the results obtained in field test bench. Similar methods or test track are already part of standard for the earth moving machinery using square bumps (UNI 12100, 2010; BS UNI 1032, 2009; BS UNI 13059, 2008). But the square shape required in these last standards has not been retained the proper one for agricultural tractor because the response could be filtered or amplified from different combinations of tires and speed. The chosen type of solicitation for this study was that of the ramp.

2. Material and methods

2.1. The experimental design

The measurement of the accelerations on the 3 axis (x, y, z) has been carried out with 3 tractors in 72 records each for a total of 648 measurements. The 72 records are the sum of the repetitions of twelve test conditions; these last have been obtained by the combination of six test surfaces with seven forward speeds (depending from the test surface) as showed in Table 1. The acceleration were analyzed both in time and in frequency domains.

2.2. The tractors

Tests were carried out by means of three medium-range tractor equipped with: i. four-wheel drive (4WD) transmission; ii. 80–90 kW rated power engine; iii. closed suspended cabin; iv. suspended seat.

2.3. The test tracks

As reported in Table 1, six different test tracks were adopted.

The ISO 5008:2002 (2002) standard test track (S1 – Fig. 1a) is the 100 m long one (smooth track) composed of two different parallel, non-deformable lanes (left and right). It was made of wooden beams 80 mm wide and 80 mm spaced with different standardized height (ranging from 20 to 160 mm) to induce vibrations. Two field surfaces, with different mechanical characteristics (penetration resistance and skeleton percentage of the upper layers), have been considered:

- a soft ground with high skeleton percentage (S2 – Fig. 1b);
- a compacted soil with medium skeleton percentage (S3 – Fig. 1c).

With reference to the classification made by the European Soil Bureau Network (ESBN) and with the World Reference Base for Soil Resources (European Commission, 2005), the soil can be classified as an Haplic Luvisol, which is a typical soil in the northern parts of Italy. A mechanical analysis of the soil texture of the fields,