Laboratory vibration measurement from hand-held harvesters for olives

Manetto G., Cerruto E., Schillaci G.
University of Catania. Di3A, Section of Mechanics and Mechanization
Via Santa Sofia, 100 – 95123 Catania, ITALY.
Tel 0039 0957147515, Fax 0039 0957147600, gmanetto@unict.it

Abstract
Vibration represents the most important risk connected with the use of portable harvesters for olive and other drupe. This research was developed within an inter-laboratory test (Round Robin Test – RRT) with the purpose of measuring the vibration to the hand-arm system produced by one portable harvester. To standardise the measurement under load conditions, a suitable laboratory test bench was used. This paper reports the results obtained by the Section of Mechanic and Mechanisation of the D*i*3A.
The results showed an average acceleration of 2.6 m s^{-2} in idling running and of 13.6 m s^{-2} under load conditions. The highest component was always along *x* direction (12.8 m s^{-2} under load), the lowest in *y* direction (1.8 m s^{-2} under load). The test bench proved to be a useful tool to standardise the test conditions, but further studies are necessary to compare acceleration values measured with the test bench and during harvesting.

Keywords: Safety, Olive Harvesting, Vibration Exposure, Hand-Arm System

Introduction

There is a large use of portable harvesters in olive growing aimed at reducing the harvesting costs. The several types available on the market are generally deficient in terms of safety and ergonomics; weight, lack of comfort, high levels of noise and vibration are the most studied aspects (Blandini *et al*., 1997; Deboli *et al*., 2008; Pascuzzi *et al*., 2008). Vibration is probably the most important risk connected with their use, often underestimated by workers, mainly interested in productivity and then exposed to the appearance of the Raynaud syndrome.

Acceleration values reported in literature present great variability (Monarca *et al*., 2007; Pascuzzi *et al*., 2009; Cerruto *et al*., 2010; Çakmak *et al*., 2011; Cerruto *et al*., 2012; Aiello *et al*., 2012; Calvo *et al*., 2014; Deboli *et al*., 2014), so the assessment of the effective risk requires the direct measurement under real working conditions.

This research was developed within an inter-laboratory test (Round Robin Test – RRT), coordinated by Roberto Deboli from the Institute for Agricultural and Earth-moving Machines of Italian National Research Council (CNR), Torino. The RRT had the purpose of measuring the vibration to the hand-arm system produced by one portable harvester. To standardise the measurement under load conditions, the CNR designed and made available to several laboratories a suitable test bench, but each laboratory carried out the measurement using their personnel and equipment. This paper only reports the results obtained by the Section of Mechanic and Mechanisation of the Department of Agricoltura, Alimentazione e Ambiente (D*i*3A).

The laboratory test bench for vibration measurement

The laboratory test bench consists of a square frame 50 cm × 50 cm with a mesh of 5 cm (vertical) × 4 cm (horizontal) of synthetic threads (Figure 1). The horizontal threads have to be subjected to tension manually and then locked by means of clamps, while the vertical ones are pulled by 1 kg masses. This system ensure an almost constant resistance to the rods of the harvesting head, simulating the canopy action.

The frame is applied to a wood structure, made stably by means of suitable weights on its base. The working height is from 140 cm to 190 cm above the ground, so allowing the test of portable harvesters with an angle of about 45°, as usually it happens during the harvesting of olives from trees.

The portable harvester

The portable harvester used for the experimental tests is driven by an electric motor powered by an external 12 V DC battery. Its harvesting head carries the motor and 8 carbon fibres rods, 350 mm long and with diameter of 5 mm. The running frequency, according to the manufacturer specifications, is about 1400 beats per min under load conditions; an electronic card and a software control the rotation speed of the motor, reducing its value at about 400 rpm in idling condition, so to reduce energy requirements and noise and vibration level. The aluminium-made bar is telescopic, with lengths of 1.55–2.60 m and diameters of 25–28 mm.

The experimental activity

Measurements were carried out both at idling and at full load conditions. The machine was only tested with the minimum bar length (1.55 m). Idling tests were carried out with the bar angled of about 45° and each measurement lasted 30 s. Full load measurements were carried out by using the test bench. To this end, the rods of the harvesting head were inserted into the frame at a depth of about 8 cm. After 5–10 s, the rods were extracted and then re-inserted in a different position of the frame, so simulating the harvesting action in an effective olive tree. The measurement time under load conditions lasted 2 min. Measurements were carried out with the machine driven by four operators and replicated five times for each operator.

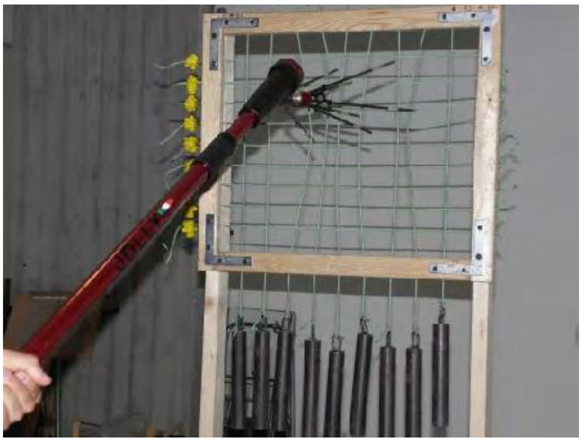

Figure 1. View of the test bench designed at the CNR for vibration measurement.

Figure 2. Accelerometer positioning on the bar and reference axes (1: *x*-axis; 2: *y*-axis; 3: *z*-axis).

Acceleration was measured, at different times, next to the hand positions on the bar, at a distance of 85 cm (M1: rear position, near the hand-grip; M2: front position, on the bar) (Figure 2). Weighted rms (root mean square) acceleration values were computed for each reference axis by applying the 1/3 octave analysis in the frequency range 6.3–1250 Hz and then the global weighted acceleration a_{hw} was calculated. Global values were statistically analysed to detect significant differences related to measuring point and working condition.

Results and discussion

The statistical analysis (Kruskal-Wallis test) of a_{hw} values showed that the only significant difference (p-level = 0.05) was that between working conditions (Figure 3): on average, the global weighted acceleration was 2.6 m s^{-2} in idling conditions, 13.6 m s^{-2} when using the test bench. Further researches will be developed to compare the results between test bench and harvesting conditions: if the difference will be not significant, the test bench may be an effective tool to standardise the test conditions for portable harvesters. The difference between rear (M1) and front (M2) position was not statistical significant: 8.5 vs. 7.8 m s^{-2}. Finally, the differences between operators were not significant too: acceleration values ranged from 7.4 up to 9.0 m s^{-2}.

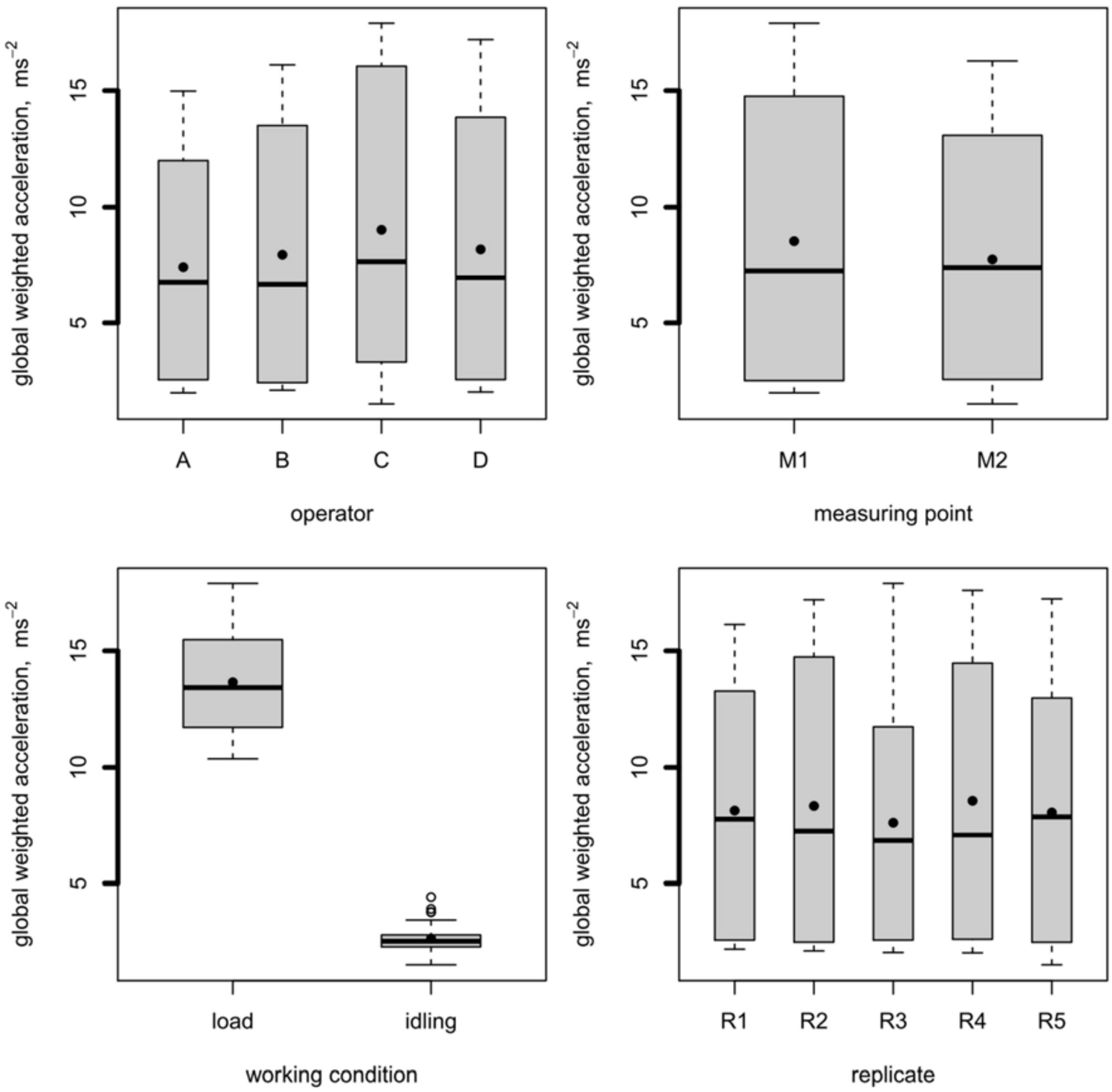

Figure 3. Box-plot of global acceleration values at varying operator, measuring point, working condition and replicate. Points represent mean values.

Weighted acceleration components along the reference axes are reported in Figure 4 at varying the working conditions. In both test conditions, the highest component was that along the *x*-axis, the lowest that along the bar axis (*y*-direction). During idling running, the average *x*-component was 2.1 m s^{-2}, the *y*-component 0.5 m s^{-2}, the *z*-component 1.2 m s^{-2}. The corresponding values under load conditions were 12.8 m s^{-2}, 1.8 m s^{-2} and 4.3 m s^{-2}. So, the interactions between rods and threads of the test bench determined an increase in all the acceleration components from 2.3 (*y* axis) to 5.1 times (*x* axis).

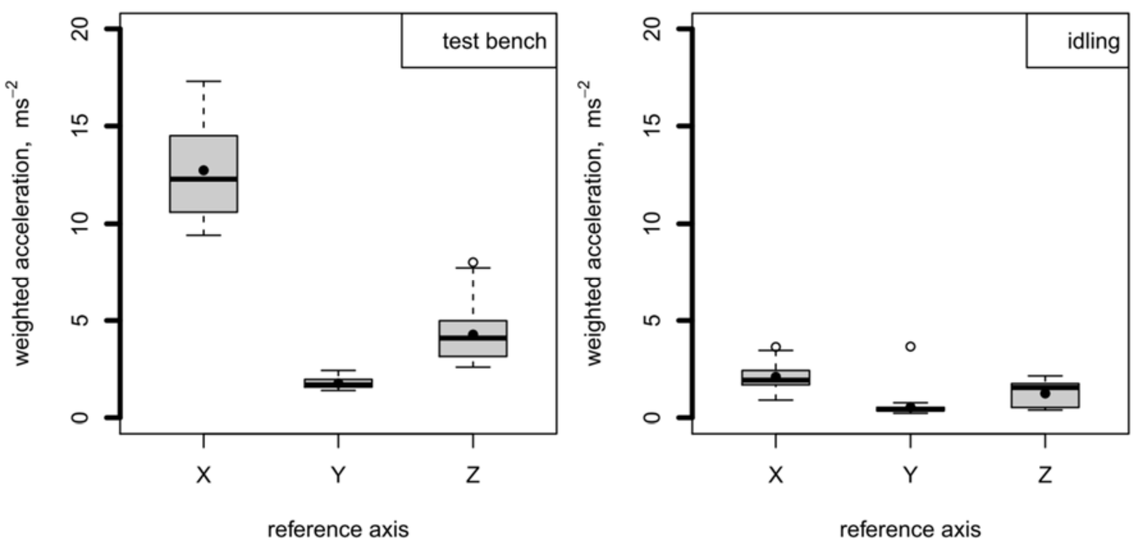

Figure 4. Box-plot of acceleration components values at varying working condition. Points represent mean values.

Conclusions
Portable harvesters for olive harvesting are generally characterised by high levels of vibration and then their use may increase the risk for the safety of the operators. The results of this research confirm this consideration and a lot of studies are still necessary to improve the ergonomic aspects of these machines, mainly regarding the kinematic of the harvesting head.

The average weighted rms acceleration value under load conditions was near 14 m s^{-2}: assuming a daily exposure time equal to 4.5 h (Calvo *et al.*, 2014), the corresponding daily vibration exposure value was 10.5 m s^{-2}, much higher than the action (2.5 m s^{-2}) and limit (5.0 m s^{-2}) threshold values established by the Italian regulation 81/08.

The test bench could be a useful tool to standardise the test conditions. However, further studies are necessary to compare acceleration values measured with the test bench and under harvesting conditions.

References
Aiello G., Catania P., La Scalia G., Piraino S., Salvia M., Vallone M. 2010. Risk assessment of hand-arm vibration in different types of portable shakers for olives harvesting. Proc. Int. Conf. "Work Safety and Risk Prevention in Agro-Food and Forest Systems", September 16–18, Ragusa, Italy, CD-ROM, Italy, CD-ROM.

Blandini G., Cerruto E., Manetto G. 1997. Rumore e vibrazioni prodotti dai pettini pneumatici utilizzati per la raccolta delle olive. Proc. AIIA, September 11–12, Ancona, Italy, 4, 229–238.

Çakmak B., Saraçolu T., Alayunt F.N., Özarslan C. 2011. Vibration and noise characteristics of flap type olive harvesters. Appl. Ergonom. 42, 397–402.

Calvo A., Deboli R., Preti C., De Maria A. 2014. Daily exposure to hand arm vibration by different electric olive beaters. Journal of Agricultural Engineering 2014, vol. 45, 3, 103–110.

Cerruto E., Manetto G., Schillaci G. 2010. Vibrations produced by electric shakers for olive harvesting. Proc. Int. Conf. "Work Safety and Risk Prevention in Agro-Food and Forest Systems", September 16–18, Ragusa, Italy, CD-ROM.

Cerruto E., Manetto G., Schillaci G. 2012. Vibration produced by hand-held olive electrical harvesters. Journal of Agricultural Engineering, vol. 43, n. 2, 79–85.

Deboli R., Calvo A., Preti C. 2008. The use of a capacitive sensor matrix to determine the grip forces applied to the olive hand held harvesters. Proc. Int. Conf. "Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-food Systems", September 15–17, Ragusa, Italy, CD-ROM.

Deboli R., Calvo A., Gambella F., Preti C., Dau R., Casu E.C. 2014. Hand arm vibration generated by a rotary pick-up for table olives harvesting. Agric Eng Int: CIGR Journal, 16(1), 228－235.

Manetto G., Cerruto E. 2013. Vibration risk evaluation in hand-held harvesters for olives. Journal of Agricultural Engineering, vol. 44 s2, 705–709, Viterbo, Italy, September 8–12, 2013.

Monarca D., Cecchini M., Colantoni A., Bedini R. 2007. Indagine sul rischio da vibrazioni al sistema mano-braccio nell'uso degli agevolatori meccanici nella raccolta delle olive. Proc. Conv. Naz. III, V e VI Sezione AIIA, Pisa e Volterra, Italy, 3, 61–4.

Pascuzzi S., Santoro F., Panaro V.N. 2008. Study of workers' exposures to vibrations produced by portable harvesters. Proc. Int. Conf. "Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-food Systems", September 15–17, Ragusa, Italy, CD-ROM.

Pascuzzi S., Santoro F., Panaro V. 2009. Investigation of workers' exposure to vibrations produced by portable shakers. Agric. Eng. Int. CIGR J. 11, 1–10.

R Core Team, 2012. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available from: http://www.R-project.org/.