International Journal of Industrial Ergonomics 53 (2016) 86–92

Contents lists available at ScienceDirect

International Journal of Industrial Ergonomics

journal homepage: www.elsevier.com/locate/ergon

A round robin test for the hand-transmitted vibration from an olive harvester

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ARTICLE INFO

Article history:
Received 27 October 2014
Received in revised form
2 September 2015
Accepted 26 October 2015
Available online 19 November 2015

Keywords:
Olive harvester
Hand-arm vibration
Round robin test

ABSTRACT

In this paper we present the outcome of a Round Robin test carried out to validate a proposed standard procedure to measure the acceleration produced by an hand held olive harvester. Ten independent laboratories using a custom-built device were involved. The device was developed to simulate olive tree branches as far as their interaction with the harvester sticks is concerned.

Collected data were analysed according to the ISO 5725-2 procedure. Accelerations measured in three of the ten laboratories were found by a cluster analysis to be statistically different from those of the remaining seven laboratories. Based on this evidence, results from the three stray laboratories were eliminated from the final sample.

Laboratory data were shown to be statistically consistent with field data in the dominant front and rear X axes as well as in the rear Z axis. No statistically significant discrepancy were found for the front and the rear acceleration vector sums, which are the quantities used to quantify the occupational exposure. The procedure developed in this Round Robin test could represent a viable basis for a future test standard for hand-held olive harvesters.

Relevance to industry: Olive beaters are devices characterized by high vibration levels transmitted to the hand-arm system. Because of the lack of a harmonized C standard, manufacturers struggle to report reliable acceleration values in the instruction manuals, as requested by the 2006/42/EC Directive. This work could help EN working groups to draft a C standard for the measurement of vibration of hand-held olive beaters.

1. Introduction

The detachment of olives by means of a hand held harvester is not an easy task, because of the small mass and high attachment strength of the drupe (Fridley et al., 1972; Tsatsarelis, 1987). Among the different types of hand-held olive harvesters which are commercialized (beaters, combs and hooks), beaters are the most widely used. Beaters, usually pneumatic or battery powered, consist of a head equipped with oscillating carbon fibre sticks (with a 5–10 mm diameter). The head is supported by a telescopic aluminium pole, which can be up to 3.5 m long. The impact of sticks on the olives or on the willowy branches causes the fruit detachment.

Hand-held harvesters are known to produce strong vibration, and their prolonged use may cause the so called Hand-Arm Vibration Syndrome (HAVS) of the muscle-skeletal, nervous and vascular peripheral structures of the upper limb (Bovenzi, 1998, 2005).

The EU directive 2006/42/EC (also known as Machinery Directive) mandates that commercialization of a tool should always be accompanied by detailed information which also include data on vibration emission. Such data are usually collected using standard tests, where actual operating conditions are simulated. By providing a rigid test protocol, the aim is to make test conditions identical in different laboratories, so that results, while possibly not fully representative of actual working conditions, can be reliably compared. The majority of existing vibrating tools, including hand held olive harvesters, lacks such standard test methods to measure vibration. Vibration data are accordingly either entirely omitted by

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http://dx.doi.org/10.1016/j.ergon.2015.10.006
0169-8141/

manufacturers or at best are measured according to generic standards, so that they cannot claim any relationship to actual field data.

In this paper we present the outcome of a round robin test where the vibration of one olive harvester has been measured by ten independent laboratories. Similar tests have been carried out on angle grinders (Liljelind et al., 2010) mostly aimed at elucidating the various concurring sources of variability.

The results found in this paper could represent the basis for a future standard where a common test method is established, that can be used by all manufacturers to simulate field operations using a laboratory device, and guarantees both repeatability and reproducibility as well as vibration magnitudes close to field values.

2. Methods

2.1. The tree-simulator

The test method proposed in this work is based on a custom built device (Deboli et al., 2014; hereafter "tree simulator") intended to provide a good approximation of the olive tree branches in terms of their interaction with the harvester. Investigations of hand-transmitted vibration make frequent use of simulators, since these devices allow the study to be carried out under better controlled and repeatable laboratory conditions (McDowell et al., 2012). The tree simulator consists of a rectangular wooden frame (500 mm high and 600 mm wide) with nine vertical and nine horizontal regularly spaced wires (Fig. 1).

Multifilament polypropylene UV stabilized wires, braid 16 spindles, 4 g/m specific mass, 90 kg breaking load are used: they are soft and pliable, but provide good mechanical resistance. The upper end of each vertical wire is secured to the frame, whereas the lower end is left free and loaded with a 1 kg iron mass (Fig. 1) in order to create an adequate tension: field measurements show in fact that an average force of 10 N is required to laterally bend the smaller twigs (diameter 2–5 mm) by 2–3 cm. The horizontal wires (spaced 40 mm apart and secured at both ends to the frame with a pretension load of 10 N) interweave the vertical wires. Masses of 1 kg were initially added to the right end of each horizontal wire of the device, to reproduce a 10 N force (to simulate the presence of larger twigs, as observed in field). After pre-tensioning, the wires were blocked and the load was removed. The tree simulator is supported by a wooden chassis so that its geometric centre is located at a height of about 1750 mm above the ground. The total mass, including the nine 1 kg iron masses, is 15 kg. The tree simulator was designed and originally assembled by the Institute for Agricultural and Earth-moving Machines of the Italian National Research Council, in Turin (hereafter "IMAMOTER").

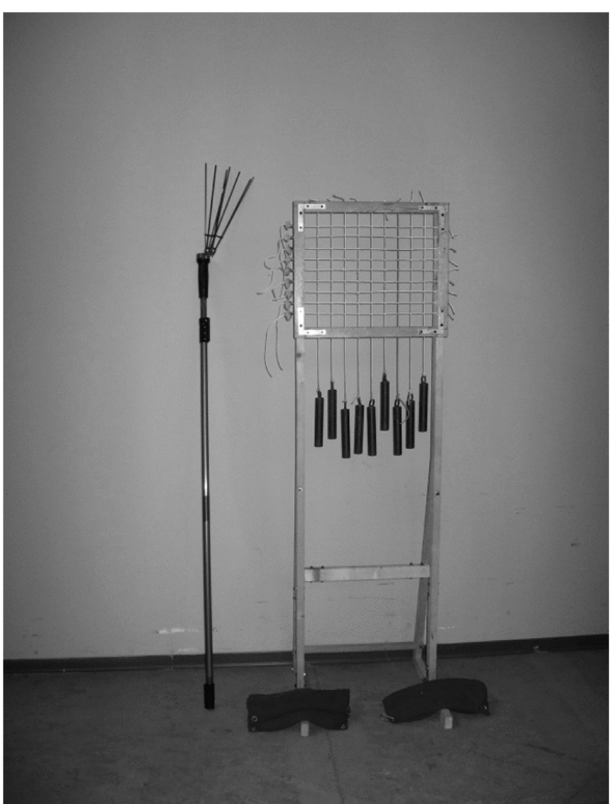

Fig. 1. The tree simulator with the harvester.

2.2. The olive harvester

All tests were carried out using a battery powered (12 V) beater with a head equipped with eight oscillating carbon fibre sticks.

All technical characteristics are summarized in Table 1. A cylindrical, metallic 1830 mm long pole was used in all tests. The beater featured electronic control to lower the number of beats per minute from 1400 to 400 when idle. The interaction of the strings of the tree simulator (Fig. 2) with the harvester sticks induced a vibration of the latter, that was transmitted by the pole to the operator hands and arms.

2.3. Measurements

2.3.1. Measurement protocol

The tree simulator was separated into four quadrants, bounded by black ribbons positioned on the frame (Fig. 2). The operator was instructed to direct the beater head to the tree simulator, and make the sticks collide with the wires in a specific quadrant, for a period of 10 s. Red ribbons were glued on the sticks 8 cm from the tip, to show the operator the right portion to be inserted through the tree simulator wires. He then proceeded to move the beater head (with no pause) clockwise to the adjacent quadrant, where the sticks remained again for 10 s, and so on until test completion after 2 min. The test timing was set by a chronometer which emitted a buzz every 10 s. The requirement to direct the sticks to a specific area was intended to simulate conditions similar to those encountered in field measurements, where the operator is forced to tighten the front grip to precisely address given tree areas.

The operator worked always with the machine at full throttle, through the entire 2 min measurement time. At no time during the test did the harvester switched to the idle mode. Accelerations were calculated as r.m.s. at the end of the 2 min measurement time.

Table 1
Summary of the harvester characteristics.

Quantity	Unit	
Working capacity	kg/h	100–400
Beats per minute	bpm	400–1400
Head mass	g	750
Telescopic pole mass	g	900
Telescopic pole length	mm	1700–3100
Stick length	mm	350
Stick diameter	mm	5
Supply voltage	V	12
Current consumption	A	2–5
Standby consumption	A	0.5
Tangential stick speed at the tip	m/s	4.14