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Design and test of a device for acceleration reproducibility of hand held olive harvesters

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ABSTRACT

Hand held olive harvesters may cause severe HAV (Hand Arm Vibration) pathologies to the operators. The measured vibration data should be available to the end users in the instruction manual issued by the manufacturers, who should follow the procedures specified by a C type European standard.

Since the hand held olive harvesters do not have such a standard, manufacturers are not able to provide reliable data. This paper describes a test methodology in view of a C type European standard for these machines.

The work started with field activities to collect acceleration data to compare with laboratory results, as requested by the EN ISO 20643. A device to simulate the dynamic vibration response of olive tree branches was then designed, assembled and tested with different configurations, to obtain repeatable acceleration data of hand held olive harvester. When the final prototype was configured, a second laboratory was involved, equipped with a different measurement chain to test the reproducibility.

Relevance to industry: This paper describes the use of a new custom built device (designed and assembled by the Authors) to simulate the dynamic vibration response of olive tree branches, to obtain repeatable acceleration data of hand held olive harvester. Laboratory tests showed that device can support companies in their task of designing safe and health hand held olive harvesters.

1. Introduction

In many Mediterranean countries the olive groves are often on sloping terrain, where the self propelled harvesting machines are unable to work. Therefore the harvesting operations are performed manually, with low productivity and high costs, up to 50–70% of the cultivation revenue (Vieri and Sarri, 2010): these drawbacks are contrasted by the hand held harvesters (powered by an external pneumatic or electric source or by a small two-cycle engine). The fall of the olives is forced by the hand held harvesters by means of the mechanical impacts of special oscillating tools or the shaking of the branches (typical action generated by the hook type machines).

The detachment of the olives is not easy and several factors contribute to the difficulty of removing them. The olive is a small fruit with high attachment strength, generally borne on long hangers which hang downward, isolating the fruit from the applied vibration. A further difficulty is that many trees are old and have brittle scaffold branches weakened by disease or grafts (Fridley et al., 1972; Tsatsarelis, 1987).

The main three types of hand held olive harvesters are: beaters, combs and hooks (Fig. 1).

Beaters are machines with an oscillating head equipped with thin sticks in carbon fibre; harvesting is obtained by direct impact of sticks on olives or by vibration transmitted to the willowy branches. Normally the head is supported by 2 or more telescopic aluminium poles, up to 3.5 m in length. These machines are normally pneumatic or battery (12 V) powered.

Electrical or pneumatic combs (flap type) have two combs with aluminium or plastic sticks moved back-and-forth, like a scissor. Normally the movement is carried out by a small piston fed by a pneumatic circuit at a pressure of 7–8 bar. Some models are battery powered (12 V). The heads can be mounted on extension poles of different lengths.

Hook type harvesters are driven by a little two-cycle engine or by an electric motor. They have a hook at the top of the pole. The engine produces an alternative motion of the pole and, therefore, of the hook. During the work the operator grabs the olive branch with the hook, which moves the branch with high frequency, detaching the fruits.

Being the hand held harvesters low weight machines, typically from 2 up to 15 kg, their working tools generate high vibration

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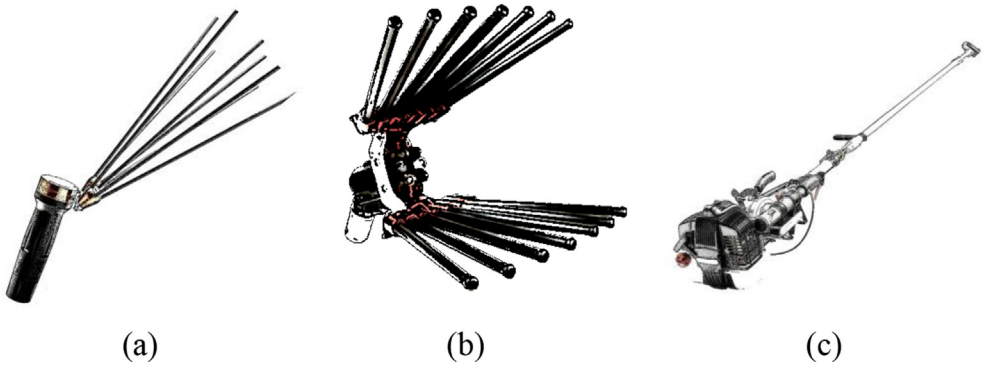

Fig. 1. Three types of hand held olive harvesters: beater (a), comb (b) and hook (c).

levels (in some models 30 m/s^2 as r.m.s. of Wh weighted acceleration are usual) which are transmitted to the operator hands.

The prolonged use of hand held vibrating power tools can result in the so called hand arm vibration syndrome (HAVS) of the muscle-skeletal, nervous and vascular peripheral structures of the upper limb (Bovenzi, 1998, 2005).

Many researchers studied the olive harvesting made through self propelled machines that shake the log (Erdoğan et al., 2003; Torregrosa et al., 2009) or the main branches (Sessiz and Özcan, 2006) of the plants, whereas the olive harvesting made through hand held devices received less attention.

Torregrosa et al. (2006) published a paper on a hook type machine used to harvest apricots. In 2008 Torregrosa et al. studied the same machine when used to harvest peaches. Though the authors were primarily interested in the mass of fruits harvested, they report maximum acceleration peaks of 900–1000 m/s^2 and a maximum root mean square (r.m.s.) value of about 230 m/s^2 at 21 Hz (not frequency weighted).

Deboli and Calvo (2009) studied the grip forces applied by the operator to the handle of held olive harvesters using a capacitive sensor matrix.

Aiello et al. (2010) studied the level of operators' hand arm vibration exposure using three different hook type harvesters, reporting acceleration values of about 12 m/s^2.

Saraçoğlu et al. (2011) carried out tests on noise and vibration produced by some hook type olive harvesters and found that the vibration level transmitted to the hands produced finger blanching in 10% of the exposed operators after about seven months.

Çakmak et al. (2011) investigated the same issues in a flap type olive harvester and obtained similar results.

Manetto et al. (2012) studied the influence of materials used in flap-type harvester: the vibration generated by carbon fibre bars had r.m.s. values of about 12 m/s^2 vs about 21 m/s^2 generated by aluminium bars.

Nevertheless exposed workers have a wrong perception of the exposure effects to HAV, as underlined by Costa et al. (2013) and Vergara et al. (2008), which may pose health problems because of the lack of preventive actions.

Beside the scientific circles, the performance of the hand held olive harvesters is of great interest because, according to the 2006/42/EC Directive (2006), the manufacturers must declare the acceleration values in the machine instruction manual. The hand held olive harvesters are treated by a B type standard (EN ISO, 20643:, 2008) which establishes that the vibration measurements in laboratory must be within the range of measurements of the field tests, with low variability. As stated in EN ISO 12100: 2010, type B standards (generic safety standards) deal with one safety aspect or one type of safeguard that can be used across a wide range of machinery. Specifically, type B1 standards concern particular safety aspects (e.g. safety distances, surface temperature, noise), while type B2 standards treat of safeguards (e.g. two-hand controls, interlocking devices, pressure sensitive devices, guards). The vibration on hand held olive harvesters are therefore treated as B1 type standard.

The results from different laboratories must differ within specified limits (reproducibility condition), with well defined operating conditions close to the real process for which the machine was designed. Unfortunately, a C type standard to establish these operating conditions for these machines does not actually exist.

It should be therefore necessary to write a standard which could give the opportunity to the manufacturer to simulate the field operations using a device exploitable in laboratory and which guarantees repeatability and reproducibility characteristics (other than vibration magnitudes close to the field values).

To fill the gap, the Institute for Agricultural and Earth-moving Machines of C.N.R. (Italian National Research Council) of Turin (from now on called IMAMOTER) designed and assembled a device to replace the olive tree for the vibration acquisition of hand held olive harvesters in laboratory.

A first device was equipped with olive branches taken from an olive tree, but the acceleration values were highly influenced by the elastic variation of the branches, which lost water and leaves day after day. Different frames with wires of several materials were then tested, to simulate the damping effect produced by the leaves, but only a wooden framed device with multifilament polypropylene UV stabilized wires gave good results in terms both of repeatability and reproducibility. This final device was then tested in another laboratory in Turin, obtaining data comparable with the field vibration values, as requested by the EN ISO 20643.

2. Materials and methods

The wooden framed device with multifilament polypropylene UV stabilized wires was firstly built at the IMAMOTER. Afterward, two olive harvesters, beaters type, were used in field during the harvesting season in autumn 2012: the laboratory vibration acquisition started after the measurement campaign in field.

The mean acceleration values obtained in field were the target to be reached in two laboratories (described in the 2.2 section) using the device designed, assembled and presented in this work.

2.1. The olive harvesters

Table 1 reports the characteristics of the two olive harvesters, beater type, used both in field and laboratory. They are battery powered (12 V) units, named J1 and J2, manufactured by the same company with an oscillating head equipped with eight carbon fibre sticks.