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Review article

Vibration and impulsivity analysis of hand held olive beaters

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ABSTRACT

To provide more effective evaluations of hand arm vibration syndromes caused by hand held olive beaters, this study focused on two aspects: the acceleration measured at the tool pole and the analysis of the impulsivity, using the crest factor. The signals were frequency weighted using the weighting curve W_h as described in the ISO 5349-1 standard. The same source signals were also filtered by the $W_{h\text{-}bl}$ filter (ISO/TS 15694), because the weighting filter W_h (unlike the $W_{h\text{-}bl}$ filter) could underestimate the effect of high frequency vibration on vibration-induced finger disorders. Ten (experienced) male operators used three beater models (battery powered) in the real olive harvesting condition. High vibration total values were obtained with values never lower than 20 m^{-2}. Concerning the crest factor, the values ranged from 5 to more than 22. This work demonstrated that the hand held olive beaters produced high impulsive loads comparable to the industry hand held tools.

Contents

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1. Introduction

The problem of the high vibration levels to the hand-arm system using vibrating tools and machines has been well known for many years. Epidemiologic aspects of the relationship between vibration exposure and human response have been investigated (Gemne, 1997; Bovenzi, 1998; Lundborg et al., 1998; Bovenzi, 2005).

The prolonged use of hand held vibrating equipment can lead to the hand arm vibration syndrome (HAVS) that refers to a combination of neurological, muscular, circulatory, bone and joint disorders (Griffin et al., 2003). Power or pneumatic drills in industry, chainsaws, beaters, brush cutters in agro-forestry may be the cause of HAVS. It is not completely well known how vibration causes the condition of the HAVS. Neurological and circulatory diseases are, for example, probably due to slight but repeated injuries to the small nerves and blood vessels in the fingers (Stoyneva et al., 2003).

The main parameters interested in the HAVS evaluation (as requested by the European Directive 2002/44/EC) are the vibration magnitudes (expressed as vibration total values) and the daily exposure time. The vibration total values are calculated using the ISO 5349-1, 2001 standard, to frequency weight the signals through the weighting curve W_h.

Many investigations have been addressed to study the magnitude of the vibration total values and the duration of the exposure (or both of them) in different work environments (Pyykkö et al., 1976; Palmer et al., 2000; Gerhardsson et al., 2005; McDowell et al., 2008; McCallig et al., 2010). Acceleration peaks generated by tools may also be further parameter influencing the harmfulness exposure to vibration.

It can be critical the presence of high peaks in the acceleration signal (i. e. the impulse character of vibration in some occupations), because high-frequency components may be hazardous in the aetiology of vibration syndrome. The vibration impulsivity could create shock waves in tissues and these waves may be transmitted at higher velocity and to larger body areas than non impulsive vibration (Pyykkö, 1986; Starck, 1984).

In the case of the whole body vibration evaluation, the ISO 2631-1, 1997 standard states that the r.m.s. (root mean square) method is the basis for measurements for crest factors (CF) less than 9. In cases where the basic evaluation method may underestimate the effects of vibration (high crest factors, occasional shocks, transient vibration), alternative measures should also be determined. The standard proposes two alternative measures: the running r.m.s. or the fourth power vibration dose value.

The crest factor is not considered in the hand arm vibration exposure, also if some studies were addressed to understand if it was appropriate to evaluate the severity of the hand transmitted vibration as peaks or r.m.s. accelerations (Louda et al., 1994; Ye et al., 2012).

Some investigations on the peaks presence in acceleration signals were conducted. These works were mainly addressed to the industrial sector (Engstrom and Dandanell, 1986; Starck and Pyykkö, 1986; Riedel and Münch, 1998; Burström and Sörensson, 1999; McDowell et al., 2008), while few researches on the agro-forestry area (Schäfer et al., 1984; Nakamura et al., 1998) were carried out. This is mostly due to the misperception that the farmers and the agro-forestry operators use few vibrating equipment and, whereas they use them, the exposure time is negligible. In the last years, instead, new tools generating high acceleration levels and impulsiveness, comparable to the construction and mining sectors, have been manufactured: among these equipment there are the hand held olive shakers driven by a little two stroke (or pneumatic or electric) engine.

The hand held olive harvesters have a low weight (from 2 to 15 kg, the electrics are the lightest). The main causes of the elevated vibration levels caused by these machines are their lightness, the high tangential velocity of their sticks tips and the pole features (material, diameter and length, Manetto et al., 2012).

The beater mass must be low because the operator inserts the beater sticks into the foliage about 30–40 times/minute for more than 4 h/day.

The high tangential velocity of sticks tips is also necessary to detach the olives. These fruits have a negligible mass (e.g. the fruits of the *Leccino* cultivar have an average mass of 1.4 g) but a great force is necessary to detached them from the branches (the average fruit removal force for the Leccino is 2.8 N), as Lavee et al. (1982) studied.

The result of the two components (tool lightness and high detachment force) is the high acceleration level, which fixes around 15–25 ms^2 (Monarca et al., 2007; Pascuzzi et al., 2009; Cerruto et al., 2009; Aiello et al., 2010; Çakmak et al., 2011; Deboli et al., 2014).

It is therefore interesting to analyse the vibrational behaviour of these machines not only considering the vibration total level, but also the frequency analysis of the signals, as requested by the Annex F (Informative) of the ISO 5349-1.

This standard requires to report (unweighted) one-third-octave band r.m.s. acceleration amplitudes on the frequency range of the measurement system, in addition to frequency weighted magnitudes. Unfortunately nobody applies this standard request.

Aim of this work was to analyse the acceleration signals in field operations using three different types of electric hand held olive shakers used by ten male operators.

These hand held harvesters have an electric engine and are called beaters: they have a head with oscillating carbon fiber sticks and the harvesting is obtained by direct impact of sticks on olives or by vibration transmitted to the willowy branches.

The values analysis was carried out weighting the signals with both the standardized frequency weighting filter W_h (ISO 5349-1) and the band limiting weighting filter $W_{h\text{-}bh}$. The latter is a weighting filter with a flat frequency range between the cut-off

Table 1
Technical characteristics of the tested beaters.

Technical data	#1	#2	#3
Beats per minute (bpm)	1086	1300	400–1400
Mass without power cord (g)	2200	2200	1650
Telescopic pole length (mm)	2500–4500	2200–3400	1700–3100
Sticks number	6	6	8
Sticks length (mm)	360	360	350
Stick diameter (mm)	10	6	5
Stick mass (g)	19.3	25.6	11.2
Stick material	Carbon fiber	Special composite	Carbon fiber
Supply voltage (V)	12–24	12	12
Current consumption (work) (A)	5–4	4	2–5
Current consumption (stand by) (A)	–	–	0.5
Engine position	rear	front	front

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