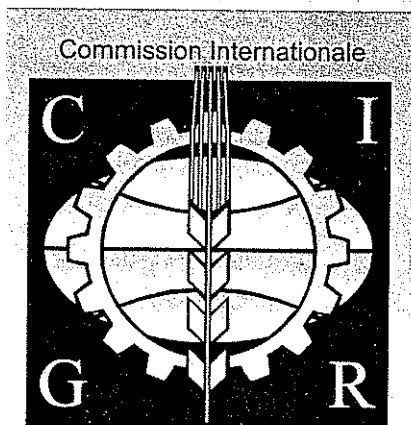


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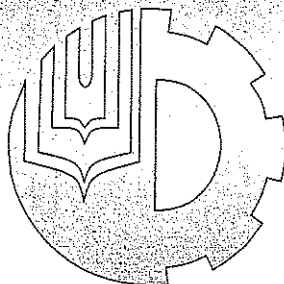


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Exposure to hand-arm and whole-body vibrations for workers employed to blowers

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Summary

Six portable blowers were chosen in order to evaluate the potential risks to operators through their exposure to hand-arm and whole body vibrations. These evaluations are based on internationally standards, with particular reference to Italian legislation of August 19th, 2005, nr 187 (directive 2002/44/EC), which lays down specific measures regarding exposure to mechanical vibration and its affect on health and measures regarding exposure to mechanical vibration and its affect on health and safety. All the levels of accelerations normalized to 8 hours have been measured and referred to a 7 hours daily period of exposure, and all results checked against the exposure limit values.

Key words: portable blowers, vibration risk, hazelnut harvester

Introduction

There are a number of specific hazards for men and women working in the agricultural and forestry sectors. A number of these hazards, such as vibration, tend to be underestimated as a potential health risk, even by the people exposed to them in their working environment, the symptoms of permanent damage and ill-health only becoming apparent years later. Overlooking the problem is not an option, as prolonged exposure to vibration can have serious health repercussions. This paper is offered as a contribution towards evaluating the risk from vibration in the use of portable blowers, a tool in widespread use throughout Italy, but particularly in the Province of Viterbo during the hazelnut harvest. Particular emphasis is placed on the risk to operators of portable blowers in the arm and hand region (which for ease of reference will from here on be referred to 'arm-hand') and for the overall body. The whole procedure is one of direct measurement with the relevant instruments for reading levels of vibration, the same method used for each of the six models analysed. There follow all the legal provisions and the most recent ISO regulations. The data obtained should help towards verifying whether specific models of portable blowers correspond to the provisions laid down in D.Lgs 187/05. Also laid out are some standard obligations on the part of employers for guaranteeing the health and safety of their employees.

Material and Methods

The implementation of directive 2002/44/EC for minimum standards of health and security for workers exposure to risk as a result of vibration" as put forward in legislative regulation n 187 of August 19th, 2005, saw the arrival of the 2002 directive on our statute books. The

decree was published in the official Gazette of the Italian republic on September 21st and come into force on January 1st, 2006. The text of D.Lgs 187/2005 largely reiterated the contents of the 2002 directive, organised into thirteen articles with a technical index. Essentially the document lays down the principal obligations of employers for the protection and security of those of their employees exposed to mechanical vibration, obligations flowing from already existing European legislation. The most controversial aspect centred around the debate in local communities regarding the fixing of new limits of exposure, particularly to vibration transmitted across the entire body. In article 3 guidelines were laid down for vibrations transmitted to the arm-hand area and to the entire body, bringing into effect a series of obligations based on limits to the rate of exposure and the rate operation to hand-arm. The limit to the rate of daily exposure to vibration was based on a time period of 8 hours, A(8), corresponding respectively to 5 m/s² r.m.s. for vibration transmitted to the hand-arm area and 1,15 m/s² r.m.s. for vibrations transmitted to the entire body. The action level of daily exposure was again based on a time period of 8 hours, A(8), corresponding respectively to 2,5 m/s² r.m.s. for vibrations transmitted to the hand-arm area and 0,5 m/s² r.m.s. for vibrations transmitted to the entire body. The action level represents general rates of exposure to which operators may be subjected and which require specific protective measures (e.g. training sessions for workers on specific risk, intervention to reduce the level of risk, periodic health and safety checks on people exposed to risks, etc.) while the limit to the rate represents a level of exposure which it is forbidden to exceed (exposing employees to an unacceptable risk without adequate protective devices).

The portable blowers are rather diffused machine for agricultural and gardening use. They are endowed with internal combustion engines and they have the specific function to generate an air flow. The air flow is expelled from a long rigid tube: the tube has a flexible base allowing a complete range of movements and facilitating the work. Two shoulder-belts are used to support unit on operator's back. The part of the machine that is in contact with the body of the operator (dorsal zone) is generally provided with a stuffing to avoid wounds and to decrease the vibrations transmitted during work. For the attenuation of vibrations all models are endowed with "silent blocs". A blower can be used for several aims: the most known and diffused use of the blower in the province of Viterbo (central Italy) is for the hazelnut harvest. Mature fruits detach from the plants and disperse on the ground. During harvest hazelnuts are piled or aligned in rows using blowers; therefore a vacuum harvesters or an harvester with automatic picking system picked up the product.

This paper takes in examination six different models of portable blowers: Echo PB 6000; Shindaiwa EB 8510; Shibaura KB 60; Shindaiwa EB 630; Zenoah Komatsu EB 7000; Efco SA 2062. The tested machines were not new, but they was already used for different years.

The evaluation of vibrations transmitted to workers by the portable blowers was done measuring the weighted accelerations according to the EN ISO 5349-1-2 :2001 for hand-arm vibrations (HAV) and the ISO 2631-1:1997 for whole body vibrations (WBV).

The measured acceleration values, for a period of exposure $T_e = 8$ hours, coincide with the values of daily exposure normalized to 8 hours A(8). This is deduced by the following formula:

$$A(8) = a_{hw} \sqrt{\frac{T}{T_0}}$$

where: T is the length of daily exposure to $a_{h,w}(s)$;
 T_o is the reference time: 8 hours (28800 s);
 $a_{h,w}$ is the value of quadratic acceleration weighed in frequency (it's the quadratic average sum of $a_{h,w}$ expressed in m/s^2 measured on the axes).

Nevertheless, the exposure time for operators employed to use of blowers is often less than 8 hours: times for fuel restocking and breaks must be considered. So the exposure time to vibration was quantified in seven hours ($T_e = 7$ hours).

The accelerations transmitted to whole body and to hand-arm was measured during different operational conditions: idling speed; maximum speed; working conditions.

Tests have been conducted using (figure 1): a triaxial accelerometer Deltatron® by Brüel & Kjær model 4506; three channels interface for human vibrations Brüel & Kjær model 1700; integrating sound level meter Brüel & Kjær Investigator 2260.

Before tests, instruments were calibrated by means of a generator of sinusoidal vibrations; an exciter calibrator Brüel & Kjær model 4294 able to generate an acceleration of 10 m/s^2 rms at a frequency of 159,2 Hz. The calibrator was used on the accelerometer to verify the gauging of the measurement system for x , y and z axes.



Figure 1. Triaxial accelerometer, 3-channels interface, sound level meter.

The accelerometers used for HAV measurement was fixed on the handle of the blowers, in proximity of the position assumed by the hand of the operator, under the ordinary operational conditions without influencing the grasping and the modality of workmanship normally adopted by the operator. The cables of the accelerometers, with the purpose to avoid troubles in the signal or risks of breaking, have been fixed in proximity of the transducer through adhesive ribbon.

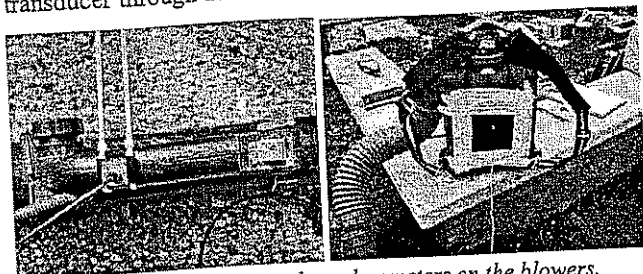


Figure 2. Mounting of triaxial accelerometers on the blowers.

The transducer used for the measure of the WBV consists in a removable triaxial accelerometer built into a semi-rigid rubber (figure 2) according to ISO 2631. The rubber was fixed through adhesive ribbon on the blower (on the surface of contact between the body and the source of vibrations). Also in this case the cables of the accelerometer have not been forced and they have not been left free to oscillate.

The tests were carried out during the period of the hazelnut harvest in the Cimini mountains, in September 2006. The length of the measurements for the HAV was 120 seconds for each sample (each axle). The EN ISO 8041:2005 standard establishes, with the purpose to minimize the error, to acquire every sample for at least 20 seconds.

For the WBV evaluation, the measurement time was 4 minutes for each axle. The ISO 8041 standard fixes the least measurement time for every sample in 1 minute.

Results

Hand-arm vibrations

Table 1 shows the levels of the HAV. For each column are respectively suitable the values $A(8)$, $A_{(w)sum}$ and $a_{Hw} max$.

Table 1. Hand-arm vibrations : $A(8)$ for 7 and 8 hours of exposure, and $a_{Hw} max$.

Model	Operational conditions	$A(8)$ $T_e = 7 \text{ h}$ (m/s^2)	$A_{(w)sum}$ (m/s^2) = $A(8)$ rif. $T_e = 8 \text{ h}$	a_{Hw} max (m/s^2)
Echo PB 6000	idling speed	1,01	1,08	1,78
	maximum speed	1,33	1,42	3,31
	working conditions	2,40	2,57	9,48
Shindaiwa EB 8510	idling speed	1,67	1,78	3,3
	maximum speed	2,45	2,62	4,58
	working conditions	1,86	1,99	4,32
Shibaura KB 60	idling speed	0,85	0,90	1,32
	maximum speed	3,17	3,39	5,97
	working conditions	3,95	4,22	7,86
Shindaiwa EB 630	idling speed	0,58	0,62	0,91
	maximum speed	1,26	1,35	2,41
	working conditions	1,19	1,27	2,37
Zenoah Komatsu EB 7000	idling speed	0,74	0,79	1,47
	maximum speed	1,96	2,10	3,66
	working conditions	2,43	2,60	4,72
Efco SA 2062	idling speed	0,47	0,5	0,70
	maximum speed	4,55	4,86	9,04
	working conditions	4,41	4,71	9,28

The equipments with daily exposure greater than $2,5 \text{ m/s}^2$ (action limit) are:

- Echo PB 6000 $A(8)$ for 8 hours at working conditions ($2,57 \text{ m/s}^2$);
- Shindaiwa EB 8510 $A(8)$ for 8 hours at maximum speed ($2,62 \text{ m/s}^2$);

- Shibaura KB 60 A(8) for 8 hours at maximum speed ($3,39 \text{ m/s}^2$) and at working conditions ($4,22 \text{ m/s}^2$);
- Zenoah Komatsu EB 7000 A(8) for 8 hours at working conditions ($2,60 \text{ m/s}^2$);
- Efco SA 2062 A(8) for 8 hours at working conditions ($4,71 \text{ m/s}^2$) and at maximum speed ($4,86 \text{ m/s}^2$);
- Efco SA 2062 A(8) for 7 hours at maximum speed ($4,55 \text{ m/s}^2$) and at working conditions ($4,41 \text{ m/s}^2$);
- Shibaura KB 60 A(8) for 7 hours at maximum speed ($3,17 \text{ m/s}^2$), and at working conditions ($3,95 \text{ m/s}^2$).

In this case the exposure limit value for each equipment tested does not overcome the limit reported in the law (exposure limit value).

Whole-body vibrations

The standard ISO 2631-1 is to define methods of quantifying WBV in relation to: human health and comfort, probability of vibration perception and incidence of motion sickness.

For the risk evaluation of the whole body vibrations, we used the multiplying factors (k): accelerations measured for each axis must be multiplied by the respective k . More specifically, for the determination of vibration risk to human health, we used the factors in relation at the posture, considered the seated-posture on the backrest.

Table 2. Multiplying factors k .

Subject position	Health (WBV)		Comfort (WBV)		
	On supporting seat surface:	On the backrest:	On supporting seat surface:	On the backrest:	Under the feet:
Seated	$k_x = 1,4$ (axis x) $k_y = 1,4$ (axis y) $k_z = 1$ (axis z)	$k_x = 0,8$ (axis x) $k_y = 1,4$ (axis y) $k_z = 1$ (axis z)	$k_x = 1$ (axis x) $k_y = 1$ (axis y) $k_z = 1$ (axis z)	$k_x = 0,8$ (axis x) $k_y = 0,5$ (axis y) $k_z = 0,4$ (axis z)	$k_x = 0,25$ (axis x) $k_y = 0,25$ (axis y) $k_z = 0,4$ (axis z)
Stranding	Under the feet: $k_x = 1$ (axis x) $k_y = 1$ (axis y) $k_z = 1$ (axis z)		Behind the feet: $k_x = 1$ (axis x) $k_y = 1$ (axis y) $k_z = 1$ (axis z)		
Recumbent			Behind the back: $k_x = 1$ (axis x) $k_y = 1$ (axis y) $k_z = 1$ (axis z)	Behind the head: $k_x = 1$ (axis x) $k_y = 1$ (axis y) $k_z = 1$ (axis z)	

Furthermore for the determination of vibration risk to human comfort, we used the recumbent - posture behind the back. Table 2 shows the multiplying factors k considered for the whole body evaluation.

Evaluation of the effects on the health from WBV

Table 3 shows the results of the measurement and A(8) for WBV.

In each column are respectively suitable the values A(8), A(w) (maximum value among: $0,8 \cdot a_{wx}$, $1,4 \cdot a_{wy}$, $1 \cdot a_{wz}$ that coincides with A(8) if exposure time is 8 hours), the acceleration of the axle more solicited among a_{wx} , a_{wy} and a_{wz} .

The daily exposures greater than $0,5 \text{ m/s}^2$ (exposure action limit) are:

- Shibaura KB 60 A(8) for 8 hours at idling speed ($0,70 \text{ m/s}^2$), at maximum speed ($0,98 \text{ m/s}^2$) and at working conditions ($1,04 \text{ m/s}^2$);
- Shibaura KB 60 A(8) for 7 hours at idling speed ($0,66 \text{ m/s}^2$), at maximum speed ($0,92 \text{ m/s}^2$) and at working conditions ($0,97 \text{ m/s}^2$);
- Efco SA 2062 A(8) for 8 hours at idling speed ($0,54 \text{ m/s}^2$);
- Efco SA 2062 A(8) for 7 hours at idling speed ($0,50 \text{ m/s}^2$);
- Zenoah Komatsu EB 7000 A(8) for 7 hours at idling speed ($0,60 \text{ m/s}^2$);
- Zenoah Komatsu EB 7000 A(8) for 8 hours at idling speed ($0,64 \text{ m/s}^2$).

Table 3. Whole body vibrations : A(8) for 7 and 8 hours of exposure.

Model	Operational conditions	A (8) rif. $T_e=7$ h (m/s^2)	$A_{(w)}$ (m/s^2) = A(8) rif. $T_e=8$ h	Axle more solicited	
Echo PB 6000	idling speed	0,15	0,17	a_{wz}	0,165
	maximum speed	0,08	0,09	a_{wx}	0,111
	working conditions	0,21	0,23	a_{wx}	0,284
Shindaiwa EB 8510	idling speed	0,23	0,24	a_{wz}	0,243
	maximum speed	0,23	0,24	a_{wz}	0,241
	working conditions	0,27	0,29	a_{wx}	0,359
Shibaura KB 60	idling speed	0,66	0,70	a_{wx}	0,876
	maximum speed	0,92	0,98	a_{wy}	0,701
	working conditions	0,97	1,04	a_{wy}	0,743
Shindaiwa EB.630	idling speed	0,40	0,43	a_{wz}	0,425
	maximum speed	0,29	0,31	a_{wz}	0,306
	working conditions	0,30	0,32	a_{wz}	0,324
Zenoah Komatsu EB 7000	idling speed	0,60	0,64	a_{wz}	0,641
	maximum speed	0,45	0,48	a_{wz}	0,478
	working conditions	0,40	0,43	a_{wz}	0,431
Efco SA 2062	idling speed	0,50	0,54	a_{wz}	0,539
	maximum speed	0,36	0,39	a_{wz}	0,387
	working conditions	0,36	0,38	a_{wx}	0,476

Evaluation of the effects on the comfort from WBV

Table 4 shows the results related to the evaluation of the comfort of the six blower models, each column is respectively suitable the values A(8) and A(w)sum.

The daily exposure greater than $0,5 \text{ m/s}^2$ (exposure action limit) is:

- Shindaiwa EB 8510 A(8) for 8 hours at working conditions ($0,54 \text{ m/s}^2$);
- Shindaiwa EB 8510 A(8) for 8 hours at working conditions ($0,51 \text{ m/s}^2$);

- Shibaura KB 60 A(8) for 8 hours at maximum speed (1,14 m/s²) and at working conditions (1,12 m/s²);
- Shibaura KB 60 A(8) for 7 hours at maximum speed (1,07 m/s²) and at working conditions (1,05 m/s²);
- Zenoah Komatsu EB 7000 A(8) for 8 hours at idling speed (0,75 m/s²), at maximum speed (0,571 m/s²) and at working conditions (0,601 m/s²);
- Zenoah Komatsu EB 7000 A(8) for 7 hours at idling speed (0,70 m/s²), at maximum speed (0,53 m/s²) and at working conditions (0,56 m/s²);
- Efco SA 2062 A(8) for 8 hours at idling speed (0,6 m/s²), at maximum speed (0,51 m/s²) and at working condition (0,731 m/s²);
- Efco SA 2062 A(8) for 7 hours at idling speed (0,56 m/s²) and at maximum speed (0,68 m/s²).

The daily exposure greater than 1,15 m/s² (exposure limit value) is:

- Shibaura KB 60 A(8) for 8 hours at idling speed (1,43 m/s²);
- Shibaura KB 60 A(8) for 7 hours at idling speed (1,34 m/s²).

Table 4. Whole body comfort vibrations: A(8) for 7 and 8 hours of exposure.

Model	Operational conditions	A (8) rif. T _e = 7 h (m/s ²)	A _{(w)SUM} (m/s ²) = A(8) rif. T _e = 8h
Echo PB 6000	idling speed	0,23	0,25
	maximum speed	0,17	0,178
	working conditions	0,39	0,42
Shindaiwa EB 8510	idling speed	0,26	0,277
	maximum speed	0,26	0,274
	working conditions	0,51	0,543
Shibaura KB 60	idling speed	1,34	1,43
	maximum speed	1,07	1,14
	working conditions	1,05	1,12
Shindaiwa EB 630	idling speed	0,45	0,482
	maximum speed	0,36	0,388
	working conditions	0,45	0,486
Zenoah Komatsu EB 7000	idling speed	0,70	0,75
	maximum speed	0,53	0,571
	working conditions	0,56	0,601
Efco SA 2062	idling speed	0,56	0,6
	maximum speed	0,48	0,512
	working conditions	0,68	0,731

Discussion

The evaluation of risk from exposure to vibrations, produced by portable blowers, was carried out taking in consideration all the references of law and standards. The D.Lgs.

187/05 (directive 2002/44/EC) prescribes the obligation for employers to assess the risks due to vibrations for the workers during work. The level of exposure to mechanical vibration may be assessed by means of observation of specific working practices and reference to relevant information on the probable magnitude of the vibration corresponding to the equipment or the types of equipment used in the particular conditions of use, including such information provided by the manufacturer of the equipment. D.Lgs. 187/05 consents to assess the risk on the base of data available on "official" database. In Italy, at the moment, is available the database ISPESL, but this database doesn't contemplate the portable blowers. To fill this gap, considering the diffusion of the blowers in the province of Viterbo (but also on the whole national territory), specific measurements are necessary.

With the aim of guaranteeing repeatable measurements, we referred to the method defined for hand-arm vibrations by the ISO 5349 standard and for the whole body vibrations by the ISO 2631 standards. It is necessary to emphasize how the ISO 2631 standard doesn't provide a specific method for the evaluation of the vibrations transmitted on the shoulder and/or on the back. Awaiting to filling this gap, methods for assessment of vibrations transmitted in seat position and supine, were adopted.

We compared the $A(8)$ obtained with the values fixed by the legislation. The vibration levels measured on the six blowers tested in working conditions, respect the exposure limits (both HAV and WBV). So, it is not necessary that the employer prepares immediate interventions for the reduction of the exposure to vibrations. Anyway, there are differences of emission among different models. In absolute the best blowers (from the health point of view) are the Echo PB 6000 and Shindaiwa EB 630.

Using the blowers Shindaiwa EB 8510 and Zenoah Komatsu 7000 in working conditions, $A(8)$ does not overcome the exposure action values (both HAV and WBV). These models are not very comfortable: the evaluation of the discomfort (WBVcomfort) shows the overcome of exposure action level (respectively $0,51 \text{ m/s}^2$ and $0,56 \text{ m/s}^2$). The model Efco SA 2062 exposes the workers to $A(8)$ greater than exposure action values for hand-arm vibrations ($4,41 \text{ m/s}^2$). This blower overcomes the action level also for WBV comfort criterion ($0,68 \text{ m/s}^2$). The model Shibaura KB 60 overcomes the exposure action values both for HAV ($3,95 \text{ m/s}^2$) and for WBV ($0,97 \text{ m/s}^2$).

At all, for the exposure to HAV low-risk situations ($A(8) < 2,5 \text{ m/s}^2$) and intermediary situations among the exposure action level and the exposure limit value ($2,5 \text{ m/s}^2 < A(8) < 5,0 \text{ m/s}^2$) emerged. A similar situation was found for WBV.

References

- Directive 2002/44/EC of the European Parliament and of the Council of 25 June 2002 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration) (sixteenth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC).
- EN ISO 10819:1996 "Mechanical vibration and shock - Hand-arm vibration - Method for the measurement and evaluation of the vibration transmissibility of gloves at the palm of the hand"
- EN ISO 5349-1:2001 "Mechanical vibration - Measurement and evaluation of human exposure to hand-transmitted vibration - Part 1: General requirements"

EN ISO 5349-2:2001 "Mechanical vibration - Measurement and evaluation of human exposure to hand- transmitted vibration - Part 2: Practical guidance for measurement at the workplace"

EN ISO 8041:2005 "Human response to vibration - Measuring instrumentation"

ISO 2631-1: 1997 "Mechanical vibration and shock -- Evaluation of human exposure to whole-body vibration -- Part 1: General requirements"

The authors contribution in this paper can be considered equal.