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Vibration Transmitted to the Hand by Backpack Blowers

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ABSTRACT

Backpack machines such as grasscutter and blower produce a vibration that is transmitted to the operator's body and hand. Prolonged exposure to vibration can cause injuries known as Hand-Arm Vibration Syndrome. One of the machines used widely in the agriculture sector is the blower. The objective of this study was to evaluate the level of vibration exposure emitted by blowers according to the method in the International Standard ISO 5349. Vibrations emitted by two backpack machines, mist blower and leaf blower, were acquired on ten subjects who were working and using the tools daily. Vibrations were recorded at operational and idle modes using an accelerometer installed in an aluminium palm adapter that was placed between the hand and the surface of the handle. The study has found that the median weighted W_h vibration magnitudes emitted by blowers to the hand were between 1.71 and 2.91 m/s^2 r.m.s. acceleration for operational and idle modes, respectively. The mist blower has an idle mode weighted W_h vibration magnitude greater than its operational mode, whilst the leaf blower has an operational mode weighted W_h vibration magnitude greater than in its idle mode. This study suggests that vibrations emitted to the hand from a leaf blower and a mist blower can be greater than the exposure action value set by the European Directive 2002 if used for more than 7 hours (mist blower) or 5 hours (leaf blower) per day. Companies that use both machines should set appropriate actions and regulations to reduce the exposure, especially to workers using the machines daily.

Keywords: Hands, vibration, hand-arm, vibration syndromes, mechanized blower.

INTRODUCTION

Backpack machines such as grasscutters and blowers are widely used in agriculture, landscaping, and gardening due to their mobility. Operating these machines gives reaction to hazardous vibration that is harmful to humans if the vibration exposure is not monitored. This can be in the form of hand-arm vibration syndrome such as the infamous vibrating white fingers [1–6]. In European countries, companies are required to monitor the vibration exposure to the hands according to the European Directive 2002/44/EC [2]. The level of vibration exposure of an 8-hour reference period of vibration, $A(8)$ shall not be greater than 5.0 m/s^2 (this value is the exposure limit value or ELV) and an action to be taken on tools that with A(8) of greater than 2.5 m/s^2 (this value is the exposure action value or EAV).

Hand-arm Vibration Syndrome (HAVS) is a recognisable problem in Malaysia. Studies have found symptoms and signs among construction workers exposed to vibration to the hand suggesting HAVS in Malaysia [4, 7, 8]. However, there is no rules and

legislation on the level of vibration exposure in Malaysia. Besides that, these workers are immigrants and are employed in industries that are not protected under our national social security schemes.

Used for different purposes, the mist blower and the leaf blower are operated by creating a high-velocity air stream through rotating impellers and eventually pushing the air through an opening. They are available in several configurations including gas-powered blower, battery-powered blower, hand-held unit and backpack style unit. The machine is carried on the back of the worker, sucks air in and blows it at high speed through a front pipe handled by the hand. Safety concerns of blowers are usually associated with the noise they produce. However, vibrations from blowers to the hand can be high, ranging from 1.27 to 4.71 m/s^2 [9] which are greater than the exposure action value set by the European Directive 2002. It has been suggested that the working time for using backpack motorized devices to be less than 1 hour per day [5].

The mechanical impedance of the hand depends on many factors such as contact area [10–14], contact force [12, 15–19], the posture of the hand [15, 18, 19], the direction of vibration [15], and frequency of vibration [11, 14]. The changes in these factors will consequently affect the vibration transmitted to the hand. A change in the magnitude of vibration has less influence on the mechanical impedance of the hand [16]. The mechanical impedance of the hand at frequencies greater than 500 Hz increases with increasing magnitude of vibration [20], but another study has found that it is negligible at frequencies greater than 100 Hz [16]. The anti-vibration glove was designed to be able to attenuate vibration to the hand [21] but some studies have found that the performance can be different depending on the contact area [13], contact force [17], location of vibration [22, 23], and frequency of vibration [23].

In this study, vibrations from backpack powered tools were measured and assessed based on the International Standard ISO 5349 [24, 25]. The vibrations were then evaluated and compared to the action and limit values set by the European Directive 2002. It was expected that the weighted W_h magnitude of vibration transmitted to the hand is greater at idle speed than at operational speed because of the high-frequency vibration at the operational speed.

METHODOLOGY

An experiment was conducted to measure vibration transmitted to the hand on two machines: a leaf blower and a mist blower. The two machines were selected due to their widespread use in Malaysian companies working in plantations as well as grounds keeping (Figure 1).

Experimental Procedure

A tri-axial accelerometer (Dytran 3263M8) was installed in an aluminium adapter that was placed between the hand and the handle (Figure 2). The vibration was recorded for about 10 seconds with a sampling rate of 4096. The accelerometer was connected to a data acquisition box and to the computer.

(a)

(b)

Figure 1. Picture of (a) leaf blower and; (b) mist blower used in the experiment.

Ten subjects participated (five subjects participated in the experiment with the leaf blower and another five subjects participated in the experiment with the mist blower) the experiment consisted of two parts which were measurements of vibration at idle speed and at operational speed. The characteristics of the ten subjects are as shown in Table 1.

Table 1. Subjects characteristics participated in the experiment (median value).

Subjects	Age (Years)	Weight (kg)	Height (cm)	Tool
1	24	60	167	Leaf Blower
2	43	61	160	
3	24	34	150	
4	30	55	155	
5	36	70	165	
6	65	86	157	Mist Blower
7	49	83	152	
8	34	60	152	
9	50	60	165	
10	34	53	167	
Median	35	60	159	

The subjects were asked to operate their tool at operational mode for 10 seconds while doing his or her normal job operation. The palm adapter was placed between the

hand and the surface of the handle. Vibration from the handle was then measured and recorded. The subjects were then asked to repeat the same procedure for idle mode.

Figure 2. Palm adapter located at the interface of the hand and the handle (in circle).

Calculation and Analysis

The magnitude of vibration in three coordinates, a_{hv} was calculated using Eq. (1).

$$\mathbf{a}_{hv}=\sqrt{\mathbf{a}_{hwx}^2+\mathbf{a}_{hwy}^2+\mathbf{a}_{hwz}^2} \quad (1)$$

where a_{hwx}, a_{hwy} and a_{hwz} are the frequency-weighted r.m.s. acceleration (weighted W_h according to International Standard ISO 5349 [24]) in the direction of x, y and z.

The time taken to reach exposure action value or exposure limit value (as defined in the European Directive 2002), the equation based on the level of vibration exposure, $A(8)$, were used and rearranged as in Eq. (2).

$$\mathbf{t}=(\mathbf{T}_{(R)})(\mathbf{A(8)}/\mathbf{a}_{hv}) \quad (2)$$

where t is the daily duration of vibration exposure experienced by subjects and $T_{(R)}$ is the 8 hours reference time. According to the European Directive 2002 [2], the daily limit value of the vibration exposure and the daily action value of the vibration exposure are 5.0 and 2.5 m/s^2, respectively.

RESULTS AND DISCUSSION

Vibration Magnitude of Leaf Blower

Figure 3 shows the vibration emitted by the leaf blower for the five subjects who participated in the experiment at operational mode and idle mode. The median weighted W_h magnitude of vibration was greater in operational mode at 2.59 m/s^2 r.m.s. acceleration than in idle mode at 1.71 r.m.s. acceleration. The vibration magnitudes were ranging between 1.89 and 3.73 m/s^2 r.m.s. acceleration for operational mode and between 1.53 and 2.01 m/s^2 r.m.s. acceleration for idle mode. Subject 1 has the highest magnitude

of vibration in both modes. The ranges of vibration magnitude for both modes are similar to the previous study [9].

The vibration was found to be greater in x-direction and z-direction in operational mode, but in idle mode, the vibration in y-direction was greater than in the other two directions. In the operational mode, the engine was running at a high speed that triggered a mode that caused vibration to be dominant in the z-direction, whilst at the idle mode, the engine was running a low speed which triggered a mode that caused vibration to be dominant in y-direction. However, these data can be discussed in detail if a modal analysis was conducted.

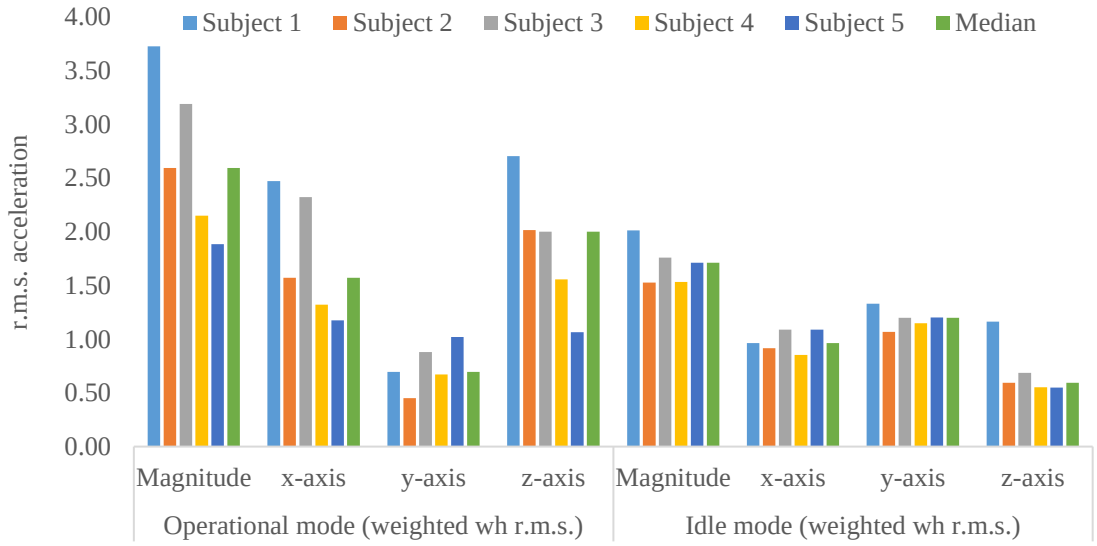

Figure 3. Vibration emitted by leaf blower at operational and idle mode.

Vibration Magnitude of Mist Blower

Vibration emitted by the mist blower measured in this study is shown in Figure 4. The vibration magnitude was highest with Subject 3 in operational mode and highest with Subject 2 in idle mode. The median weighted W_h magnitude of vibration was greater in idle mode at 2.91 m/s^2 r.m.s. acceleration than in operational mode at 2.13 m/s^2 r.m.s. acceleration. For operational mode, the magnitude of vibration was between 1.82 to 3.39 m/s^2 r.m.s. acceleration. The magnitude of vibration for idle mode, on the other hand, was between 1.98 to 5.18 m/s^2 r.m.s. acceleration.

The median r.m.s. acceleration in x-direction was greater than the y and z-directions in operational mode. Similarly, in idle mode, the median r.m.s. acceleration in x-direction was found to be greater than the other two directions. The leaf blower may have been operated at a different speed than the mist blower, thus the leaf blower in the operational mode triggered a mode different than the mist blower and caused vibration to be dominant in the x-direction, although this can be clear if a modal analysis was conducted.

Maximum Allowable Operating Time of Blowers

The time to reach exposure action value (EAV) and exposure limit value (ELV) calculated using Equation 3 is shown in Table 1. Both types of blower have a median of ELV in both

operational and idle modes greater than 24 hours. This means that workers can use both types of blower for 8 working hours per day without reaching the ELV set by the European Directive 2002.

For the leaf blower, the median hours of usage to reach exposure action value (EAV) are 7.43 hours and 17.04 hours in operational mode and idle mode, respectively. This means that when the workers used the leaf blower in the operational mode for more than 7 hours per day, the level of vibration exposure A(8) will go beyond the action limit value.

For the mist blower, the median hours of usage to reach EAV are 11.01 hours and 5.90 hours. Companies that require their workers to use mist blowers are expected to limit the hours of usage to less than 5 hours per day or they have to act to reduce the vibration exposure.

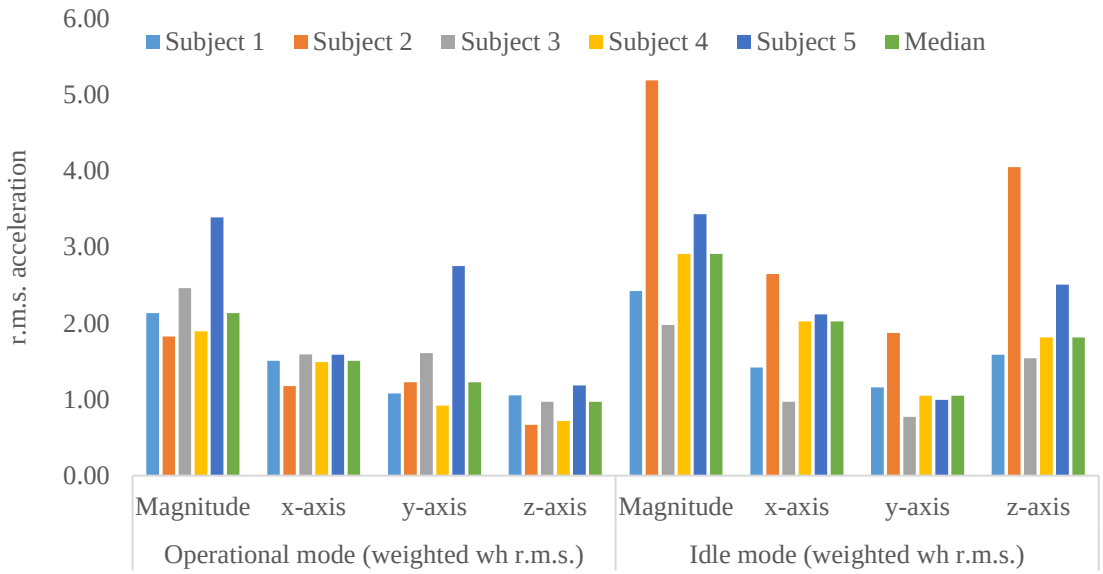

Figure 4 Vibration emitted by leaf blower at operational mode and idle mode.

It was observed that the vibrations measured at the handle varied among the subjects and this may be contributed by the effects of grip force and contact area. The subjects were asked to grip the handle tightly together with the palm adapter, but the grip force may be different among the subjects. Furthermore, the structure of the handle vibrated differently with a different grip force. The different grip force and contact area can also affect the biodynamic response of the hand [13, 17].

For the leaf blower, the value of vibration in operational mode measured in this study is better in representing the severity of the vibration emitted by the leaf blower than in idle mode because the severity is greater in the operational mode than in the idle mode. On the other hand, the mist blower emitted greater vibration in idle mode than in operational mode, thus the vibration measured in idle mode may be better to represent the severity than in operational mode.

In Table 2, both blowers exceeded the exposure action value set by the European Directive either in operational mode or in idle mode or both. The vibrations measured in this study were in-line and similar to the vibration measured by the previous study [9]. It is suggested that companies with workers using both blowers daily, to monitor the use of the blowers and limit the usage as suggested in the previous section of this paper.

Table 2. Calculated time to reach EAV and ELV for mist blower and leaf blower for operational and idle modes.

		Operational mode			Idle mode		
Tool	Subject	Magnitude, a_{hv} (m/s^2)	Time to EAV (hours)	Time to ELV (hours)	Magnitude, a_{hv} (m/s^2)	Time to EAV (hours)	Time to ELV (hours)
Leaf Blower	Subject 1	3.73	3.60	14.39	2.01	12.32	49.29
	Subject 2	2.59	7.43	29.70	1.53	21.40	85.58
	Subject 3	3.19	4.91	19.66	1.76	16.16	64.65
	Subject 4	2.15	10.82	43.27	1.53	21.26	85.05
	Subject 5	1.89	14.06	56.23	1.71	17.04	68.17
	Median	2.59	7.43	29.70	1.71	17.04	68.17
Mist Blower	Subject 1	2.13	11.01	44.03	2.42	8.53	34.14
	Subject 2	1.82	15.03	60.13	5.18	1.86	7.44
	Subject 3	2.46	8.27	33.07	1.98	12.81	51.26
	Subject 4	1.89	13.98	55.90	2.91	5.90	23.60
	Subject 5	3.39	4.35	17.42	3.43	4.25	17.02
	Median	2.13	11.01	44.03	2.91	5.90	23.60

CONCLUSION

In this paper, the magnitude of vibration emitted by two types of blowers, a mist blower and a leaf blower, were acquired and evaluated based on the method specified in the International Standard ISO5349. The vibrations were compared to the action and limit value set by the European Directive 2002.

It was found that the magnitudes of vibration, a_{hv}, for both types of blower were less than the exposure limit value (ELV) set by the European Directive 2002. However, both blowers may transmit vibration to the hand greater than the exposure action value. This study suggests that the usage of a leaf blower is to be limited to 7 hours, and the mist blower to 5 hours per day, so that the workers who work the blowers will not be exposed to vibrations greater than the action value set by the European Directive 2002. Companies are suggested to limit the hours of usage for the blowers so that the level of vibration exposure of their workers will not reach the exposure action value and causes a long-term effect on their health and well-being.

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