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Comparative Study of Two Different Types of Power Weeders

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A B S T R A C T

Hand operated farm machinery produces higher amounts of vibrations, which can cause Musculoskeletal disorders like white finger syndrome and blanching of fingers. Long term exposure to this vibration leads to fatigue and discomfort that causes lower performance efficiency of the worker. Weeding is an important operation in cultivation of row crops. Large farms require weeding machinery for proper and quick removal of weeds. Otherwise, there will be a huge loss in production that raised due to the competition between weeds and the main crop for nutrients. In this study, two different types of power weeders were taken for vibration measurement. These two are different in constructional material, weight and source of power. The vibrations transmitted to hand are higher in amar power weeder during intercultural operations i.e. 17.55 ms^{-2} at a speed of 2800 rpm. In both the power weeders, HTV increased as the speed is increased. In BCS power weeder, there are some arrangements to dampen the vibrations. It produced only 4.85 ms^{-2} and 5.20 ms^{-2} at the speeds of 1800 rpm and 2700 rpm during intercultural operations respectively. Therefore, BCS power weeder is more comfortable to the operator.

Introduction

Agriculture is the most important sector of the Indian Economy. The production of food grains for the year 2018-19 was recorded as 285.17 million tonnes, which is slightly higher than food grain output of 285.01 million tonnes in 2017-18. This is a good symptom for the Indian economy from the agriculture sector. Proper use of mechanized inputs into agriculture has a direct and significant effect on production, productivity and profitability on agriculture farms, along with labor productivity and quality of life of people engaged in agriculture. Empirical evidence confirms that there is a strong correlation between farm mechanization and agricultural productivity. States with a greater availability of farm power show higher productivity as compared to others.

With the introduction of modern technology, ergonomics becomes essential for its successful application. The important point here is that the major benefit to the agriculture is to have safe, healthy and productive worker. In farm works, the fatigue and discomfort to which human beings are subjected is not only due to physical work but also to vibration and noise as well (Huang and Suggs, 1968). The vibrations acting on the human body are called human vibration and this is classified into two types. One is whole body vibration (WBV) and another one is hand-transmitted vibration (HTV). The hand-transmitted vibration exposure during the operation of power weeder is greater than the recommended limit of ISO 5349 (1986).

Hand transmitted vibration of the power weeder is very severe as the handle is a cantilever beam and the power is obtained from a single cylinder diesel engine (Ying *et al.*, 1998). This may lead to pain in the arms and shoulders, numbness, reduced grip strength, and also circulatory disorders, as well as bone, joint or muscle diseases. These effects can further give rise to sleep disturbances and reduction of efficiency at work. Therefore, there is a need to select the power weeder that transmits vibration within the permissible limit. The objective of this study was to assess the hand transmitted vibration in two different available power weeders.

Theoretical consideration

Vibration is defined as the effect of mechanical vibration on the human body. There are two major types of human vibration: hand transmitted vibration (HTV) and whole body vibration (WBV). Hand transmitted vibration is transmitted to the hands and arms through the handle while walking behind the power weeder. It is known that the vibration entering the hand contains contributions from all three measurement directions. Therefore, the measurement should preferably be made for all three directions simultaneously. Figure.1 illustrate an anatomical and basicentric coordinate system for measurement of hand transmitted vibration exposure as defined in ISO 5349-1(2001).

Magnitude of vibration

When the human body is in contact with a vibrating mechanical device, it is displaced about its contact position (Sanders and Mccormick, 1993). Displacement is therefore one parameter which can be used to describe the magnitude of a vibration. Although displacement, velocity and acceleration can be used for quantifying the vibration severity. Human response to vibration is highly dependent on the frequency of the vibration. As per the ISO 5349(2001) recommendations, the most important quantity used to describe the magnitude of vibration transmitted to the operator's hands is root mean square (rms) frequency weighted acceleration in ms^{-2} expressed as

$$a_{hw} = \left[\sum_{j=1}^{n}\left(W_h a_{hj}\right)^2\right]^{1/2} \text{ ----------- } (3.1)$$

Where

a_{hw} = Root mean square (rms) frequency weighted acceleration

W_h= Weighting factor for j^{th} one-third octave band

a_{hj}= rms acceleration measured in one-third octave band used in ms^{-2}

n = number of frequencies used in the octave band

The weighted value should be determined over the eight octave bands (i.e n=8) from 8 to 1000 Hz or over the 24 one third octave bands (i.e n=24) from 6.3 to 1250 Hz. The one- third octave band is very common and is adopted in the ISO 5349 (2001). The sensitivity of body to different frequencies is different, so weighting factor for different frequency bands are defined in ISO 5349-1 (2001) which are given in the table.1. It is clear from the table that the hand-transmitted vibration is more sensitive to the frequency range of 6.3 to 31.5 Hz.

Vector sum of the frequency weighted acceleration (Vibration total values) in three axes represents the acute effects better than does the weighted acceleration in the main axis alone. This is the vibration total value a_{hv} and it is defined as the rms of the three component values given below

$$a_{hv}=\sqrt{(a_{hwx})^2 + (a_{hwy})^2+(a_{hwz})^2} \text{--(3.2)}$$

Where

a_{hv}=total rms weighted acceleration at the handle in ms^{-2}

a_{hwx}=rms weighted acceleration in x-axis in ms^{-2}

a_{hwy}= rms weighted acceleration in y-axis in ms^{-2}

a_{hwz}= rms weighted acceleration in z-axis in ms^{-2}

Therefore the vector sum of vibration intensity is virtually independent of the orientation of the coordinate system.

The daily vibration exposure in terms of 8-h energy equivalent was derived from the magnitude of the vibration (vibration total value) and daily exposure duration. In order to facilitate comparison between daily exposures of different durations, the daily vibration exposure were expressed in terms of 8-h energy equivalent frequency-weighted vibration total value, a_{hv} $_{(eq.8\ h)}$ as shown in the equation 3.3 as follows

$$A\ (8) = a_{hv}\sqrt{T/T_0} \text{ ----------- (3.3)}$$

Where

A (8) = Daily vibration exposure in terms of 8-h energy equivalent, in ms^{-2}

T = Total daily duration exposure to the vibration a_{hv}(h or sec)

a_{hv} = Vibration total value in ms^{-2}

T_0 = Reference duration of 8 h (28,800 sec)

The following formula was used to estimate exposure duration for finger blanching in 10 per cent of exposed persons as given in ISO-5349 (2001).

$$D_y = 31.8\ [A\ (8)]^{-1.06} \text{ ----------- (3.4)}$$

Where

D_y = the group mean total (life time) exposure duration, in years.

A (8) = Daily vibration exposure in terms of 8-h energy equivalent, in ms^{-2}

Materials and Methods

Self-propelled Power Weeder

A 5.5 hp BCS walk behind self-propelled power weeder (Figure.2) manufactured in India and commonly used by the farmer was selected for the study. The power weeder is powered with single cylinder air-cooled horizontal petrol engine of 94 kg weight. Power weeder has 46 cm rotavator to carry-out intercultural operations in different crops. The power transmission from the engine to the wheels and to the PTO is through a solid transmission in oil bath and there is a conical self-ventilating dry clutch. There was an adjustable handlebar, which can keep in 7 different positions to fit all types of operator. Handlebar mounted on silent-blocks to dampen vibrations and allow to use for several hours without straining the operator.

A commercially available Amar rotary tiller cum power weeder (Figure.3) was also selected. It is powered with 4.8 hp greaves diesel engine of 46 kg weight. It is suitable for intercultural operations in row crops. Total weight of the power weeder is 140 kg.

Vibration Analyzer

A SVAN 958, four channel vibration analyzer was used in this study (Figure.4). SVAN 958 analyzes the frequency range from 0.5 Hz to 20 kHz. Each of four channels work simultaneously with independently configured input (transducer type), filters, and RMS detector time-constants. The digital signal processor can execute advanced frequency analysis simultaneously to the meter mode for real-time four-channel 1/1 octave or 1/3 octave analysis including statistical calculations, real-time four-channel FFT analysis including cross spectra, and sound intensity measurements. Vibration analyzing accomplishes requirements according to ISO-5349 (2001) and ISO-2631-1 (1997).

The vibration analyzer can measure vibration acceleration ranging from 17.8 ms^{-2} to 316ms^{-2}. A four-pin cable makes a connection between the accelerometer and the vibration analyzer. The data stored in the vibration analyzer was downloaded on a personal computer at the end of the experiment for further analysis.

Hand adapter

An adapter was used for attachment of transducer to measure the vibration intensity of hand-arm system. The adapter was made up of the aluminium alloy (Figure.5). A light weight tri-axial accelerometer was fixed by a stud in the adapter to measure hand-arm vibration. The design of the adapter was such that the accelerometer should lie in between the index and middle finger. The total weight of the adapter including the accelerometer was 28.8 g.

The adapter was arranged according to the ISO-5349 (2001) on the handle bar of the power weeder. After arranging, the adapter should act as an integral part of the power weeder, so that it can sense the actual vibration levels as of the handle of the power weeder and there should not be any vibration dampening in between the adapter and handle. The adapter was arranged on the right hand handle bar of the power weeder.

Tri-axial accelerometer

One tri-axial accelerometer was used to measure vibration magnitude (Figure.6). The accelerometer was fastened by a stud in the adapter (Figure.7). The position of hand on the handle bar was such that it followed the directions according to the ISO standard.

Tachometer

A contact type tachometer was used to measure the rotation speed of an engine. The device displays the engine speed in terms of revolutions per minute (rpm) on an analog display. The tachometer was put on the center shaft of flywheel and the engine speed was set at 2200 and 2800 rpm with the help of different accelerator level.

Plan of Experiments for Measurement of Vibration magnitudes

The field experiments were conducted at the different operational conditions. The selection of operational conditions and its level was based on review and the knowledge about the scenario of power weeder use. The different operating conditions and the measured parameters are given as below:

Results and Discussion

From the above observations, it was known that the HTV is very much higher in amar power weeder. The main reason behind this was the design. Both power weeders were designed very differently. Amar power weeder was of fully iron material including wheels also. It was heavier as compared to BCS power weeder. All covering parts of BCS power weeder were made of plastic. It has rubber tyres to reduce the vibration. Source of power also diesel engine for amar power weeder. This may also one of the reasons. Hence, BCS power weeder is better to use.

Table.1 Operating conditions independent variables

S. No.	Source of variation	Levels
1	Operational conditions (Transportation and weeding)	2
2	Engine speed (2200 and 2800 rpm)	2

Table.2 Design of experiments dependent variables

S. No.	Treatments	Levels	Particulars
1	Operational conditions	2	X = Transportation (On bitumen road) Y = Weeding
2	Engine speed (rpm)	2	A =Half throttle speed (2200 rpm) B = 3/4th throttle speed (2800 rpm)
	Replication	3	

Table.3 Mean values of vibration magnitude (ms^{-2}) for engine speed and different operational conditions in Amar power weeder

Operational conditions	Engine speed(RPM)	
	2200	2800
Transportation	13.37	14.1
Weeding	16.75	17.55
Mean	15.06	15.825

Table.4 Mean values of vibration magnitude (ms^{-2}) for operational conditions and different engine speed in Amar power weeder

Engine speed (RPM)	Operational conditions	
	Transportation	Weeding
2200	13.37	16.75
2800	14.1	17.55
Mean	13.74	17.15

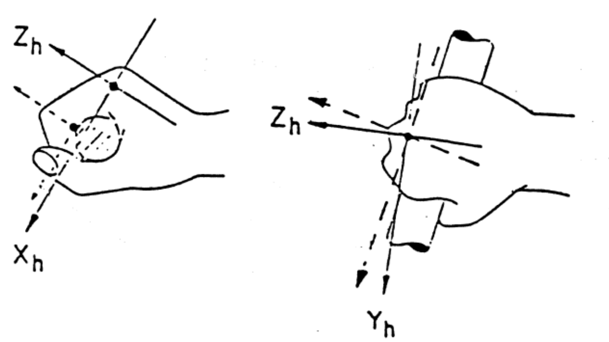
Table.5 Mean values of vibration magnitude (ms^{-2}) for engine speed and different operational conditions in BCS power weeder

Operational conditions	Engine speed(RPM)	
	1800	**2700**
Transportation	2.83	3.32
Weeding	4.85	5.28
Mean	3.84	4.3

Table.6 Mean values of vibration magnitude (ms^{-2}) for operational conditions and different engine speed in BCS power weeder

Engine speed (RPM)	Operational conditions	
	Transportation	**Weeding**
1800	2.83	4.85
2700	3.32	5.28
Mean	3.075	5.065

Fig.1 Coordinate system for hand



Basicentric coordinate system   Biodynamic coordinate system

Fig.2 BCS power weeder

Fig.3 Amar power weeder

Fig.4 Vibration analyser

Fig.5 Hand adapter

Fig.6 Accelerometer

Fig.7 Accelerometer fixed by stud in adapter

In conclusion this higher values of HTV were produced by all the iron metal parts, heavy weight if machine and iron wheels. Therefore, it will be better to reduce heavy weight and to use any mechanical measures to reduce the vibrations produced by engine like isolators or rubber interventions between the contact surfaces at the time of designing.

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