Hand-Transmitted Vibration Exposure to Tractor Operator during Tillage Operation

*Dewangan K.N., Zimik W. and Sharma K.B.N.
Department of Agricultural Engineering, North Eastern Regional Institute of Science and Technology, Nirjuli – 791 109, Arunachal Pradesh, India
*e-mail: kndewangan2001@yahoo.co.in

ABSTRACT

An investigation was conducted to quantify hand-transmitted vibration exposure to the tractor driver. Three experienced tractor operators were chosen to measure the exposure during tilling operation. Three primary tillage implements namely mould board plough, disc plough and rotavator were selected for the experiments, which were operated at three levels of forward speed, i.e., 0.98, 1.37 and 1.54 m/s. Measurements were also done during idle condition. ISO 5349 (2001) guidelines were used for measurement and analysis of hand-transmitted vibration. Latency period for occurrence of vibration white finger was also calculated. The results indicate that root mean square (rms) vibration acceleration is negligible up to 25 Hz. The peak value of vibration acceleration was observed from 500 to 630 Hz. Vibration total values (rms) were relatively more during operation of rotavator and increase in speed of operation increased vibration acceleration. The effect of speed of operation on vibration acceleration was more during operation of rotavator. Analysis of variance indicated that vibration acceleration (rms) was significantly affected during operation of tillage implements ($p<0.01$) and speed of operation ($p<0.05$).Considering 8 h per day vibration exposure, latency period for appearance of the vascular disorders among tractor drivers was less than 13 years.

Key words: Hand-arm vibration, tillage implements, steering wheel, health effect

INTRODUCTION

Agricultural tractors are used extensively for various field operations and the current population of tractor is more than 3 millions. It is expected that nearly 0.3 million tractors are added to Indian agriculture every year. Bhalla, 2007 [1] reviewed tractor market in India and suggested that for increasing the sale of tractors, it is very important to know the potential buyers specific need. Several efforts have been done to investigate the characteristics of the whole-body vibration in the tractors and its effect on operators. The studies have reported that tractor operators in India are exposed to high level of vibration during field operations. Studies have also been done to reduce whole-body vibration exposure to the operators. However, no study has been reported on hand-transmitted vibration of a tractor except the study in Goglia et al., 2003 [6]. Furthermore, there is no data on the characteristics of hand-transmitted vibration from steering wheel during various field operations.

The detrimental effects of the prolonged exposure to hand–transmitted vibration on the operators have been known for a long time. The occupational health disorders in the vascular system, bones and joints, peripheral nervous system, muscular system, and central nervous system owing to exposure of hand transmitted vibration are collectively referred as 'hand-arm vibration syndrome [7].Short term exposure of hand transmitted vibration causes discomfort and pain which result in fatigue. Operators take rest to overcome fatigue which reduces work bout and hence duration of actual work. Actually, human susceptibility depends upon different characteristics of vibration, for instance, magnitude, direction, frequency and duration of exposure [8]. Therefore, measurement and evaluation of hand-transmitted vibrations are necessary for assessing the operator's comfort. Furthermore, the magnitude of vibration depends on the manner in which the machine is used. The vibration received by an operator depends on his technique and vary according to the dynamic response of his finger, hands and arms [7].

In view of the above discussion, the present study was undertaken at North Eastern Regional Institute of Science and Technology, Nirjuli, India to quantify the hand-transmitted vibration at the steering wheel of the tractor during tillage operations under field conditions. The data were analyzed so that its consequences can be determined in light of the limits set by International Standard Organization [8].

MATERIALS AND METHODS

Three experienced tractor operators were chosen from the North Eastern Regional Institute of Science and Technology, Nirjuli, India. The operators were selected to represent 5th, 50th and 95th percentile Indian population. The subjects were healthy male operators and no muscular pain or physiological abnormalities were observed. Prior to the test, consent was taken from a Human Research Ethics Committee of NERIST for the experiments. Consents were also obtained from the subjects. The physical characteristics of the selected subjects were measured. The mean ± standard deviation of age, stature and body mass were 28.30±6.86 years, 1665±45 mm and 57.9±10.1 kg, respectively. The subjects were made acquainted with the experimental protocol to enlist their full cooperation.

Three primary tillage implements namely 2-bottom 35 cm mould board plough, 2-bottom 55 cm disc plough and 127 cm rotavator were selected, which are operated in untilled field. The selected subjects were required to operate the tractor and perform tillage operations with the implements. The engine was operated at rated speed, i.e., 1898 rpm, while the tractor was operated at three gears (L_2, L_3 and H_1) during tillage operations. The forward speeds of 0.98, 1.37 and 1.54 m/s were obtained in L_2, L_3 and H_1 gears, respectively.

A two wheel drive tractor commonly used in India was selected for the experiments. Specifications of the tractor are given in Table 1. A light weight tri-axial piezoelectric accelerometer (356A22, PCB, USA), four-channel real time multi analyzer (OR34, OROS, France) and NV Gate software (OROS, France) was used to measure vibration characteristics of the tractor. For measuring vibration at the steering wheel of the tractor during field operation, the accelerometer was mounted on a hand-adapter and the hand-adapter was fixed on the steering wheel of the tractor by nylon wire (Fig. 1).The schematic diagram of the experimental set up for measuring vibration acceleration is shown in Fig. 2. Vibration acceleration of the tractor in ideal condition was recorded in computer notebook for 30 s while vibration acceleration was recorded in the computer note book for a trial distance of 30 m. The experiment was repeated for pre-determined gear settings, subjects and implements combination. The entire experiment was replicated three times.

Table 1: Important specifications of the tractor

Engine model and type	: B-275 DI, IHBD-144A, four-stroke, 3-cylinder, water cooled, vertical diesel engine
Swept volume, cc	: 2346
Rated brake power, kW	: 22.95 at 1898 rev/min
Drawbar power, kW	: 21.63
Weight of tractor without ballast, kg	: 1627

With the help of NV Gate software (OROS, France), stored data was analyzed for vibration acceleration in root mean square (rms) ($a_{h,j}$) at 1/3rd octave band in the frequency range between 6.3 and 1250 Hz for each trial and each axis. Average of the three trials of a subject for each axis was calculated. From frequency-weighted vibration acceleration (rms) of three axes, vibration total value (a_{hv}) was calculated. Average of vibration acceleration of all the three subjects were calculated which represented vibration exposure during operation of the tractor.

Fig 1: Mounting of accelerometer and hand adapter on handle of the hand tractor

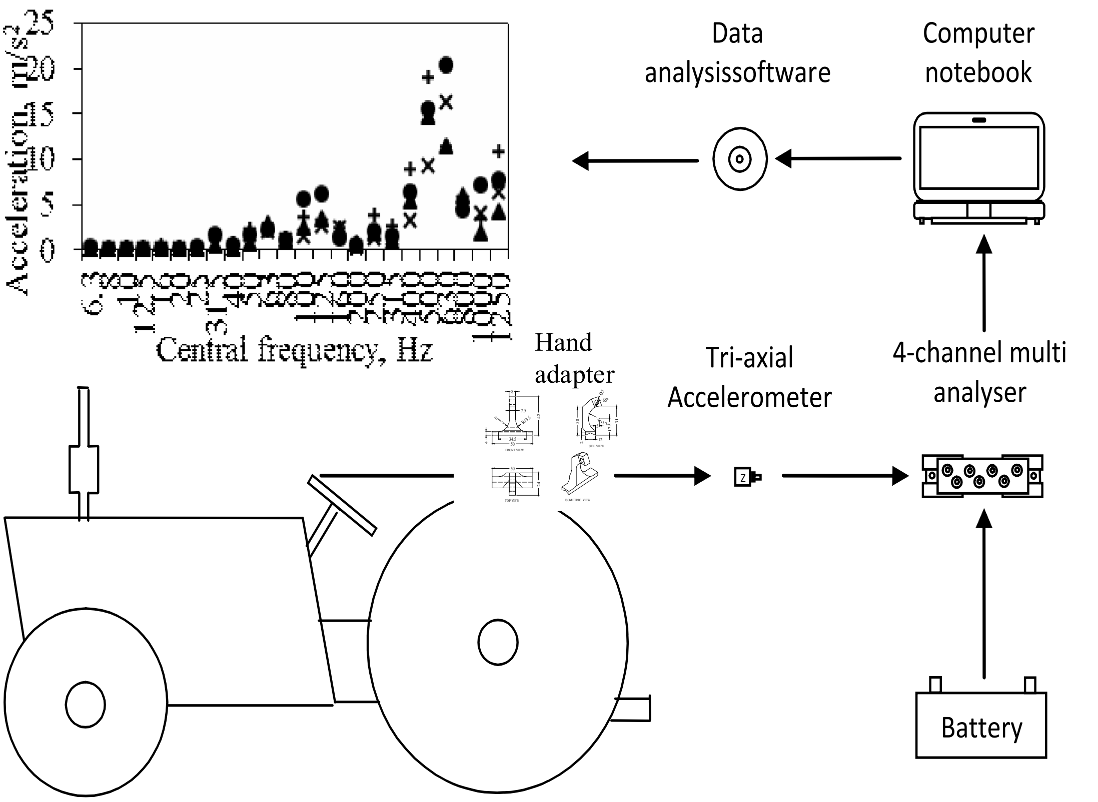

Fig 2: Schematic diagram of the experimental set up for measuring vibration acceleration in the steering wheel

RESULTS

Fig 3 shows the frequency-unweighted vibration acceleration (rms) as a function of frequency in 1/3rd octave band between 6.3 and 1250 Hz for the Y_h-axis during idle and tillage operations with various implements. It is evident that vibration acceleration up to 25 Hz is negligible. There was variation in frequency corresponding to the highest vibration acceleration. The highest vibration acceleration of 19.0 m/s^2 was observed at 500 Hz during operation of rotavator, whereas 20.3, m/s^2 was observed at 630 Hz during operation of disc plough. The highest vibration acceleration during idle condition was also observed at 630 Hz to the level of 16.3 m/s^2.Effect of speed of operation on frequency-unweighted vibration acceleration (rms) at 1/3rd octave band during operation of disc plough in the Z_h-axis is shown in Fig. 4. It was observed that the increase in forward speed increased vibration acceleration at almost all the frequencies.

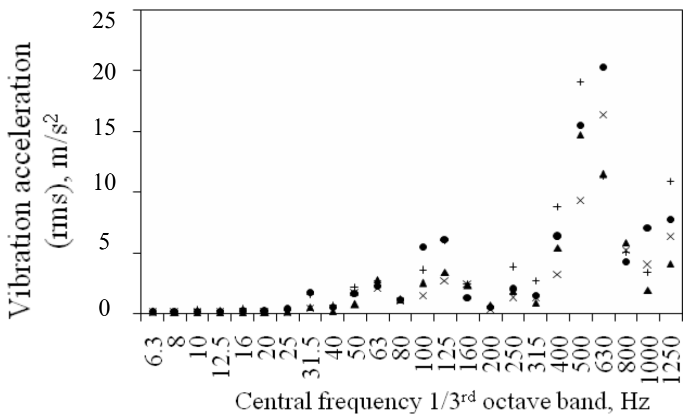

Fig 3: Relationship between frequency-unweighted vibration acceleration (rms) and frequencies at 1/3rd octave band during operation of various implements at 0.98 m/s in the Y_h-axis: ×, idle condition; ▲, mould board plough; ●, disc plough and+, rotavator

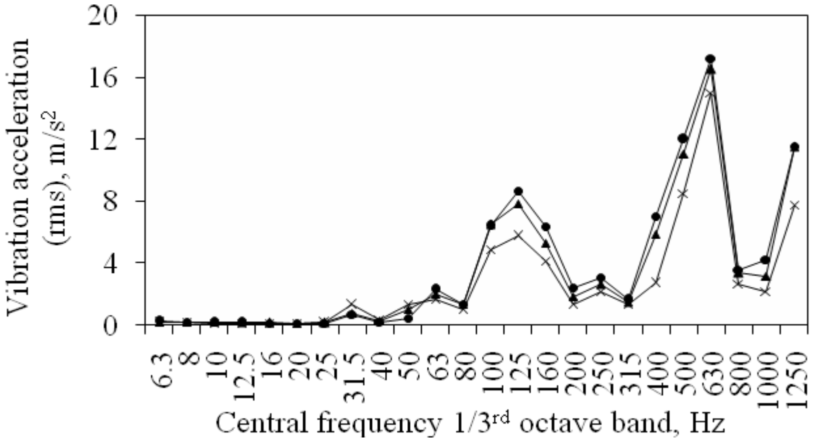

Fig 4: Effect of speed of operation on frequency-unweighted vibration acceleration (rms) at 1/3rdoctave band during operation of disc plough in Z_h-axis; ×, 0.98 m/s; ▲, 1.34 m/s and●, 1.54 m/s

Mean and standard deviation of frequency-weighted vibration total value (a_{hv}) during idle condition and operation of different tillage implements is shown in Table 2. With increase in speed of operation from 0.98 to 1.54 m/s, vibration total value increased from 2.69 to 3.54, 3.25 to 3.79 and 2.91 to 4.09 m/s^2 during operation of mould board plough, disc ploug hand rotavator, respectively. The increase of vibration total value was the highest during operation of rotavator with speed of operation.

Table 2: Vibration total value and latent periods in years for the appearance of vascular disorders of the hands in 10% of the tractor operators exposed to steering vibration during idle condition and various tillage operations as predicted using criteria in ISO 5349 (2001)

Particulars	Forward speed, m/s	Vibration total value, m s^{-2}	Latent period, year
Idle condition	–	1.88(0.17)	16.55
Mould board plough	0.98	2.52(0.05)	12.05
	1.37	2.85(0.15)	10.54
	1.54	3.54(0.67)	8.34
Disc plough	0.98	3.25(0.38)	9.15
	1.37	3.54(0.38)	8.33
	1.54	3.79(0.57)	7.74
Rotavator	0.98	2.91(0.26)	10.29
	1.37	3.29(0.28)	9.01
	1.54	4.09(0.26)	7.12

DISCUSSION

Sources of vibration in a tractor are an engine and other moving components, rapid load variation during operation due to heterogeneous soil and undulating surface of field. The unbalanced inertia force of moving parts and gas pressure of the engine of the tractor are the major sources of vibration. Fundamental frequency of vibration of moving components corresponds to its rotation speed. Fundamental frequency of vibration in the experiment was 31.5 Hz (Fig 2-4), i.e. engine speed divided by sixty. The reason for this may be the steering system of the tractor is mounted over the clutch housing which is attached to the engine. Furthermore, inertia force and gas pressure of engine fluctuate periodically. Therefore, they vibrate in the harmonics of working frequency corresponding to the rotational speed and frequency of vibration is integer multiple of the fundamental frequency. In the present study, there were several peaks of vibration at steering wheel within the frequency range of 6.3 to 1250 Hz. The prominent frequency of vibration was 31.5, 63, 125, 250, 500 and 630 Hz. These frequencies of vibration are integer multiple of fundamental frequency. Goglia et al., 2003 [6] also observed periodic fluctuation of vibration acceleration and the first fundamental frequency of vibration at full load was 25 Hz. Salokhe et al., 1995 [9] observed that the most dominant frequency of the hand tractor matched with the excitation frequency of the engine during stationary condition where the source of excitation was the moving parts of the engine only. The subsequent predominant peaks were observed at regular interval. Dewangan and Tewari, 2009 [5] observed effect of ground condition on the level of vibration in the hand tractor.

Based on the latency curve recommended in ISO 5349 (2001) and measured vibration exposure data, it is predicted that the latent period for the onset of VWF in 10% of the tractor operator are less than 14 years. However, no data is available to support occurrence of VWF among tractors operators in India. Goglia et al., 2003 [6] have expected that the vibration acceleration transmitted from steering wheel of the tractor to the driver's hand may produce finger blanching in 10% of the exposed persons in less than 2 years. According to Bovenzi, 1998 [3], there are too few epidemiology data to enable reliable conclusions to be drawn about exposure-response relationships for disorders caused by hand-transmitted vibrations. Burström and Sörensson, 1999 [4] also stated that vibration exposure required to cause hand-arm vibration disorders is not clearly known, either with respect to intensity, frequency, or with respect to daily exposure time and total exposure period. This is due not only to different individual susceptibilities to vibrations, but also to the different physical characteristic of the vibration exposure and differences between tools and occupations.

CONCLUSIONS

The following major conclusions can be drawn from the present study.

1. Vibration acceleration in root mean square (rms) was negligible up to 25 Hz during entire experiment.
2. Vibration acceleration was relatively more during operation of rototiller as compared to mould board plough and disc plough.
3. Vibration acceleration increased with increase in speed of operation and the effect of speed of operation was more during operation of rototilling.
4. Latency period for the appearance of vibration-induced white finger among the 10% tractor operators was less than 13 years, if the tractor is operated 8 h per day.

STATEMENT OF RELEVANCE

Vibration contributes to operator fatigue and can have a detrimental effect on job performance and health. Whole-body vibration exposure to the tractor drivers have been widely measured in the past while limited knowledge exists on the hand-transmitted vibration exposure to the tractor drivers.

REFERENCES

1. Bhalla D (2007). Tractor market in India – an overview.*AgrilEngg Today*, 31(3-4): 54-59.
2. Bheemsen A,Datta RK (1995). Optimization of tractor-trailer performance in hauling operation.*Agril Mechanization Asia, Africa and Latin Am*, 26(4): 59-61.
3. Bovenzi M (1998). Exposure-response relationship in the hand-arm vibration syndrome: an overview of current epidemiology research. *Int Arch Occ Environ Health*, 71: 509-519.
4. Burström L,Sörensson A (1999). The influence of shock-type vibrations on the absorption of mechanical energy in the hand and arm.*Int J Ind Ergonomics*, 23: 585-594.
5. DewanganKN,Tewari VK (2009). Characteristics of hand-transmitted vibration of a hand tractor used in three operational modes.*Int J Ind Ergonomics*, 39(1): 239-245.
6. Goglia V, Gospodaric Z, Kosutic S,Filipovic D (2003). Hand transmitted vibration from the steering wheel to drivers of a small four-wheel drive tractor. *App Ergonomics*, 34: 45-49.
7. Griffin MJ (1996). Hand Book of Human Vibration. Academic Press, London.
8. ISO5349 (2001). Mechanical vibration measurement and evaluation of human exposure to hand-transmitted vibration, part – I: general requirements. International Standard Organization, Geneva.
9. Salokhe VM, Majumder B, Islam MS (1995). Vibration characteristics of a power tiller. *J Terramechanics*, 32: 181-197.