Research article

Investigation of Vibration Characteristics of a Hand Tractor using MEMS Sensor

PHON SOVATNA*
Faculty of Agriculture, Kyushu University, Fukuoka, Japan
Email: ruasovatna@yahoo.com

EIJI INOUE
Faculty of Agriculture, Kyushu University, Fukuoka, Japan

MUNESHI MITSUOKA
Faculty of Agriculture, Kyushu University, Fukuoka, Japan

ZHEN LI
Faculty of Agriculture, Kyushu University, Fukuoka, Japan

Received 20 December 2015 Accepted 21 October 2016 (*Corresponding Author)

Abstract The increase of agricultural mechanization, especially hand tractors has been remarkably emerged in the last decade. It is known as well that agricultural mechanization not only facilitated timely completion of operations but also increased production, labor savings, energy efficiency, productivity, and profitability. With high degree of hand tractor use, providing a safe and comfortable working environment to operators became an important consideration, specifically vibration that is a main cause of early fatigues. In this study focus on measuring translational acceleration and rotational angular velocity at various locations of hand-tractor under stationary and driving modes. Root-mean-squares (RMS) and power-spectrum-density (PSD) were used to investigate vibration magnitude and dominant frequencies, and effective measurements were finally suggested. Results showed that under stationary mode largest vibration acceleration appeared at handgrip in vertical axis of about 8.5m/s^2 followed by engine top, gearbox and chassis, respectively. In driving mode, the main vibration magnitude occurs in vertical axis at about 11.8 m/s^2. Within 50Hz frequencies, predominant acceleration occurred in longitudinal axis at about 10Hz frequencies at first peak and about 18Hz frequencies at next peak at engine top. Whereas, at handgrip predominant acceleration appeared hugely in vertical axis at about 10Hz frequencies, and at the same frequency was found in pitch axis of rotational angular velocity under stationary mode. However, it appears clearly at about 9Hz frequencies in vertical axis in driving mode. Both conditions, vibration exposures are much higher than that in health risk limitation standard that operators should be prevented effectively; otherwise, to suffer from early fatigue.

Keywords agricultural tools, vibration magnitude of translational acceleration and rotational angular velocity, hand-arm vibration, and future development

INTRODUCTION

Agriculture employs almost 80% of Cambodian rural labor forces. It is considered to strongly support Cambodian people in ensuring food security (Ngo and Chan, 2010) and constitutes a main source of income (Ros et al., 2011). It is the main driver of poverty reduction (Ngo and Chan, 2010), and it has a 29% contribution to the GDP (Chao, 2009; Chan, 2013).

The enhancement of agricultural production through agricultural tools, the use of agricultural mechanization has gradually increased, specifically over the last decade (Chan, 2013). It is evident that the agricultural mechanization not only facilitated timely completion of operations but also increased production, labor savings, energy efficiency, productivity, and profitability (Singh et al., 2011). In Cambodia; therefore, many farmers sold animals to buy mechanized tools for field operations, especially hand tractors (Chao, 2009). Multipurpose uses of mechanization meant that time operation to hold handgrip became longer that induce to vibrated discomfort known as early fatigue. Tiwari et al., (2006) explained that machine vibration was detrimental to agricultural users. Many researchers also confirmed that vibration would be very harmful to health induced such as early fatigues that may cause physical, physiological and musculoskeletal disorders after long-time exposure over months and years (Salokhe et al., 1995, Sam et al., 2006).

This study measures vibration magnitude and vibration transmissibility at various locations of hand tractors such as engine top, chassis, gearbox and handgrip, hand-arm vibration exposure and suggests effective intervention for future development.

METHODOLOGY

Experimental Hand Tractor

A 12Hp hand tractor as shown in Fig. 1, under stationary and driving modes in a duration of 30 seconds with the idling speed (5 km/h) was employed in these experiments using MEMS sensor.

Fig. 1 Transportation-type hand tractor

Experimental Instrumentation

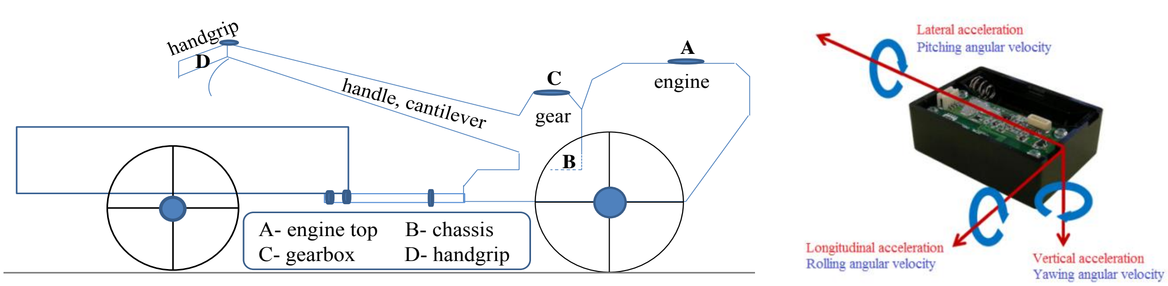

Fig. 2 Locations of experiment specification and MEMS sensor

Vibration transmission measurement at various locations of hand tractor had been carried out by many researchers, and strain gage were mostly employed for the experiments (Salokhe et al., 1995, Taghizadeh et al., 2007). However, strain gage were complicate in manipulation such as Strain Amplifier, Chanel-Data-Tape Recorder, Autonomous Data Acquisition Unit and Microcomputer with a limited connected cord. In a modern society; however, a MEMS sensor is very compact, light and easy to use. So it was chosen for this study. The wireless sensor can detect signal within 50 meters, and the output is easy to convert and calculate (Choe et al., 2013).

Data Outputting and Processing

The characteristics of hand tractor vibration are described in RMS, PSD and dominant frequencies, derived from output generation equations, Eq. (1) and Eq. (2). Vibration transmission is a proportion between engine top, main source of vibration, and connecting parts.

$$G = \frac{(V-1.65) \times 9.8}{0.19} \quad (1)$$

$$W = \frac{V-1.35}{5.6 \times 0.00067} \quad (2)$$

Where V: voltage output when translational acceleration and rotational angular velocity are in G and W, respectively (Choe et al., 2013).

Root Mean Square and Power Spectrum Density

The RMS was used to obtain vibration magnitudes, and the PSD was employed using Fast Fourier Transform (FFT) function of mathematical computation and signal processing software package to obtain frequency domain (Salokhe et al., 1995). The PSD was plotted against frequency of the signal; therefore, the dominant frequency of vibration was received from the plot.

Hand-arm vibration exposures

A quantity of three combination axes was recommended by ANSI S2.70-2006 to evaluate hand-arm vibration exposures as expressed in Eq. (3) and Eq. (4).

$$a_{hw(rms)} = \sqrt{\sum_i (W_{hi} a_{hi(rms)})^2} \quad (3)$$

$$a_{hv(rms)} = \sqrt{a_{hwx}^2 + a_{hwy}^2 + a_{hwz}^2} \quad (4)$$

Where $a_{hw(rms)}$: vibration in each direction $a_{hv(rms)}$: vibration combined value, W_{hi}: correction coefficient,a_{hwx}, a_{hwy}, a_{hwz}: each direction value.

RESULTS AND DISCUSSION

RMS of Stationary Hand Tractor

Vibration magnitudes of the 12Hp hand tractor using MEMS sensor are described in Fig. 3. It can be seen that RMS values at handgrip in vertical axis was the biggest followed by those at gearbox, engine