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Determination of Dominant Axis for Hand Arm Vibration (Hav) In Malaysian Army Three-Tonne Truck Steering Wheels

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ABSTRACT
It has been reported that vibration transmitted from the steering wheels of Malaysian Army (MA) three-tonne trucks to the drivers' hands causes discomfort and early fatigue. To this end, this paper presents the research results of hand arm vibration (HAV) from MA truck steering wheels in the *x*-, *y*- and *z*-axes in order to determine the dominant axis. HAV from the steering wheel was measured using a tri-axial accelerometer which was connected to a human vibration analyser. HAV values were collected at three speeds; 40, 80 and 90 km/h. The results indicate that root mean square (rms) vibration acceleration was highest in the *z*-axis followed by the *x*- and *y*-axes. Thus, the *z*-axis is the dominant axis for HAV in the truck's steering wheel. Daily vibration exposure *A(8)* also increased with increasing vehicle speed.

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INTRODUCTION

Hand arm vibration (HAV) is the vibration received by the hands from the use of hand tools that produce vibrations, such as concrete breakers, hand drills, chain saws and grinders. In addition, driver hands have direct contact with the surface of the vibrating parts, for example steering wheels, are not immune to HAV exposure (Aziz, S.A.A., *et al.*, 2014). There are some physical variables relevant to the effects of hand transmitted vibration, such as magnitude, frequency, direction of vibration, duration of exposure, area of contact with vibration, contact force (grip and push forces), hand posture and environment (Griffin, M.J., 1997).

The transmission and effects of vibration into the hands differ according to the direction of vibration. Vibration is measured from the steering wheel to the hand in three orthogonal directions, designated as the *x*-, *y*- and *z*-axes. The axes may be defined relative to the orientation of the hand or relative to the steering wheel (Griffin, M.J., 1997). The studies conducted by Goglia *et al.*, (2003), Dewangan and Tewari (2009), Yoo *et al.*, (2011) and Eaton (2003) on the steering wheels of tractors, Korean made passenger cars and highway buses respectively have shown that the type of vehicle, road and load condition determine the outcome of the most dominant HAV axis.

Three-tonne trucks are commonly used vehicles for carrying personal and logistics in Malaysian Army (MA) services. It has been reported that vibration transmitted from the steering wheels of the trucks to the drivers' hands causes discomfort and early fatigue. To this end, this paper presents the research results of hand arm vibration (HAV) from MA truck steering wheels in the *x*-, *y*- and *z*-axes in order to determine the dominant axis.

Computation Of Hav:

The HAV risk is based on the frequency-weighted acceleration value a_{hv}, which is given by the root-sum-of-squares of the frequency-weighted accelerations of the three orthogonal *x*-, *y*- and *z*- axes respectively:

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

Normally, a human vibration measurement device gives the rms and daily vibration exposure values, which are measured in m/s^2 (West Lothian Council, 2003) vibration exposure depends on the amount of vibration magnitude and duration of exposure incurred (Griffin, M.J., 1997). The daily exposure period is the total duration of exposure to vibration in a working day. It is fundamental to the determination of the total duration of daily exposure, and appropriate in a variety of operations and condition. The daily vibration exposure for an 8 h working day *A(8)* is calculated as:

$$A(8) = a_{hv}\sqrt{\frac{T}{T_0}} \quad (2)$$

Where T_o is the reference duration of 8 hours and T is an estimate of the time that the drivers are exposed to the vibration.

MATERIALS AND METHODS

The guidelines for the measurement and evaluation of human exposure to HAV are defined in the International Standard, ISO 5349-1. A Brüel & Kjær Type 4524-B-00 triaxial accelerometer was used to measure the HAV values of the truck's steering wheel. The accelerometer was secured at a suitable position based on the biodynamic coordinate system and basicentric coordinates of the steering wheel (ISO 5349-1). The *x*- and *y*- axes are the radial and tangential directions of the steering wheel respectively. The *z*-axis is perpendicular to the *x-y* plane and is positive in the direction towards the steering column (Yoo, W.S., *et al*., 2011). The triaxial accelerometer (Figure 1(a)), is connected to the steering wheel surface by using an adaptor with a clip for the accelerometer (Figure 1(b)), which is connected to a Brüel & Kjær Type 4447 human vibration analyser (Figure 1(c)). Before the test, the accelerometer was calibrated using a Brüel & Kjær Type 4294 calibration exciter to ensure that the obtained data is accurate and reliable. Figure 2 shows the position of the accelerometer as recommended in ISO 5349-2. The measurements were carried out at speeds of 40, 80 and 90 km/h and each speed is repeated at least 2 times to ensure the data is accurate and reliable for further analysis.

Fig. 1: Experimental setup to measure HAV in a MA three-tonne truck's steering wheel: Mounting the triaxial accelerometer (a) to the hand adapter (b) and human vibration analyser (c).

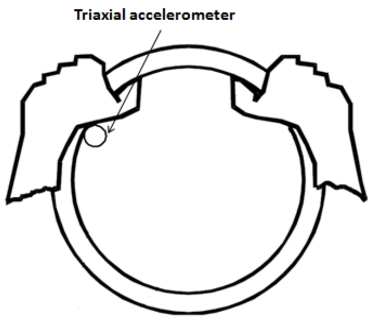

Fig. 2: Position of the triaxial accelerometer on the steering wheel (edited from ISO 5349-2).

RESULT AND DISCUSSION

Table 1 shows frequency-weighted rms vibration acceleration (rms), daily vibration exposure *A(8)* and average daily vibration exposure $A(8)_{avg}$ for the MA truck's steering wheel in the different axes. From the overall data, the rms values in the *z*-axis are the highest as compared to the *x*- and *y*-axes. This indicates that the level of vibration in the *z*-axis is the most dominant axis for MA truck's steering wheel. The vibrations from the road, truck body and engine is transferred to the steering wheel through the steering rod vibrates more in the tangential direction of the *z*-axis than vibration in *x-y* plane. In addition, $A(8)_{avg}$ also increased with increasing vehicle speed. Drivers will easily feel uncomfortable and early fatigue when driving at a higher speed. Past researches by Dewangan and Tewari (2009), Eaton (2003) and Goglia *et al*. (2003) also showed that increasing vehicle speed results in increased HAV levels.

Table 1: Frequency-weighted vibration acceleration (rms) and daily vibration exposure *A*(8) for different axes.

Vehicle Speed (km/h)	Vibration acceleration (rms), (m/s^2)			*A(8)* (m/s^2)	$A(8)_{avg}$ (m/s^2)
	x-axis	*y*-axis	*z*-axis		
40	0.420	0.315	0.492	0.720	0.644
40	0.354	0.233	0.376	0.567	
80	0.955	0.826	1.222	1.757	1.141
80	0.487	0.402	0.587	0.863	
80	0.484	0.363	0.528	0.803	
90	0.764	0.468	0.949	1.306	1.299
90	0.792	0.559	1.069	1.444	
90	0.733	0.665	1.055	1.447	
90	0.520	0.411	0.744	0.997	

Conclusion:

Based on the results obtained, it can be concluded that the *z*-axis is the more dominant axis for HAV in MA three-tonne truck steering wheels. Hence, it is recommended a one-axis accelerometer mounted on the *z*-axis on the steering wheel can be used to replace the triaxial accelerometer to measure HAV for this type of vehicle. More detailed analysis can be done by focusing only on the *z*-axis, such as acceleration integration, Fast Fourier Transform (FFT) and power spectral densities (PSD) analysis.

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