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ASSESSMENT OF RIDE COMFORT OF PASSENGERS BASED ON WHOLE BODY VIBRATION

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Abstract : Today the ride comfort plays an important role in the vehicle design as well as in vehicle judgment. There, the whole-body vibration transmission influences on comfort, performance and health condition of the passengers. However, in present, passengers have to spend a considerable amount of time for travelling without doing any precious thing. It means they waste their valuable time for travelling. A part due to long travel, passengers may have to face for some health issues such as fatigue, back injuries, vomiting etc. Objectives of this study are to investigate an impartial frequency range which will enhance the ride comfort of the passengers and to develop a relationship between whole body vibration and ride comfort. A variety of road types were selected. By using six channel vibration meter (SVANTEK 106) which was calibrated according to ISO 2631-1, 2 and 5, whole body vibration at 3 axes (fore-and-aft, vertical and lateral) was measured while passengers are performing reading and typing tasks. It was found that there is a significant effect of vibration on both reading and typing speeds of passengers. Whole body vibration exposure in fore and aft direction was found to be greatest for body vibration and are significantly correlated with reading and typing speeds.

Keywords: Passengers; Reading; Ride Comfort; Typing; Whole Body Vibration

1. Introduction

In present, people spend a considerable amount of their time for travelling. The level of comfort in private and public transportation plays a significant role in general mobility, as a result, improving ride comfort needs more attention. A comfortable ride is essential for a vehicle to obtain passenger satisfaction. Most of the vehicle manufactures seek for newly introduce methods in ride comfort. However, the ride comfort of the passengers is affected by several factors, namely, vibration induced from vehicle itself, road condition, characteristics of seats, speed of the vehicle and noise. [1]

When the vibration of the vehicle is up to 12Hz, it affects human organs. Human body at seated posture resonant at about 5 Hz in vertical vibration and about 1-3 Hz in horizontal vibration, and attributed by significant motion of several parts of the human body [2]. Due to poor conditions in vehicles, passengers may occupy muscle fatigue, back injuries, fatigue and vomiting even in one hour journey. If there is a solution for these unsatisfactory ride, passengers can use this time in a precious way like reading, sketching, writing, working with portable computers and etc.

Although condition of ride comfort in Sri Lanka is not in a good level, in developed countries it has been paid attention to improve the ride comfort. Ride comfort may associated with root mean square value (rms) and vibration dose value (VDV) as these parameters indicated energy received to human body [3].

Transportation sectors in developed countries considered that having ride comfort for passengers based on whole body vibration is a vital requirement. However, this was not attracted in developing countries, possibly because lack of awareness in field of study (i.e., ride comfort, whole body vibration etc.), no access to recent research studies. It has been often observed that, the passengers, drivers and manufactures are not aware about the conditions of the ride comfort while travelling, possibly because in our environment any of these parties is not going to improve their knowledge on this matter.

Today time management would become an essential function. Time is a key factor for the development of a country. People are needed to be motivated to use their time efficiently without any wasting. Due to poor transportation facilities and ride comfort, people have to spend more time in travelling: making them to lose their most valuable time in roads.

This research aims to introduce new, simple and accurate methods to assess and enhance ride comfort of the passengers based on the whole body vibration measurements.

2. Methodology

2.1 Field measurements

The field study was conducted on a private van in different routes by considering two main activities: reading and typing.

Six channel vibration meter (SVANTEK 106) which was calibrated according to ISO 2631-1, 2 and 5 was used. The sensor, seat pad accelerometer (SV 38V) was connected into the vibration meter. Then the sensor of seat pad accelerometer (Figure 1) was properly placed on the passenger seat. The coordinate systems were coincided with the coordinate systems which were indicated in the instrument.

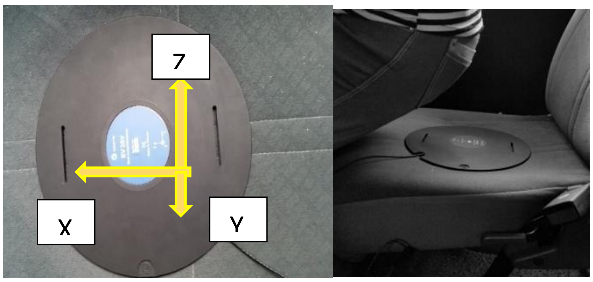


Fig 1: Sensor placed on the seat

The reading and typing speed of the passengers were determined at two conditions: with vibration and without vibration.

Before the journey started, passengers, who were sat on the seat, were instructed to perform each activity (i.e., reading and typing separately) within 5 minutes. The completed task was recorded and considered as the task performance without exposing to vibration. During the journey, passengers were instructed to perform the same two activities. The completed task for each activity was recorded and considered it as the task performance with exposing to vibration. With respect to subjective measurement, the vibration samples were recorded with integration period of 1 second. The measurement were conducted for 5 minute duration. Weighted accelerations on the passenger seat was measured as shown in Figure 2.

(a) **(b)**

Fig 2: Vibration exposure was measured while (a) reading and (b) typing

The vibration exposure levels were measured along three axis (i.e. vertical, fore-and-aft and lateral) at the seat. After the ride, the passengers responded to a questionnaire survey.

2.2 Analysis

Root mean squared (R.M.S) value, Vibration dose value (VDV), Maximum Transient Vibration Value (MTVV) and Crest Factor (CRF) were determined by using following equations.

The weighted R.M.S acceleration was determined by using Equation (1).

$$\mathbf{RMS} = \left[\frac{1}{T}\int_0^T a(t)dt^2\right]^{0.5} \qquad \mathbf{Eq\ (1)}$$

Where,

a (t) - Frequency-weighted acceleration time

T - Duration of the measurement, in seconds

Vibration Dose was calculated by using Equation (2).

$$\mathbf{VDV} = [\int_0^T a^4(t)dt]^{1/4} \qquad \mathbf{Eq(2)}$$

The resultant SI unit is $ms^{-7/4}$.

Maximum Transient Vibration Value (MTVV) was obtained by using Equation (3).

$$\mathbf{MTVV = max\ [a_w\ (t_o)]} \qquad \mathbf{Eq\ (3)}$$

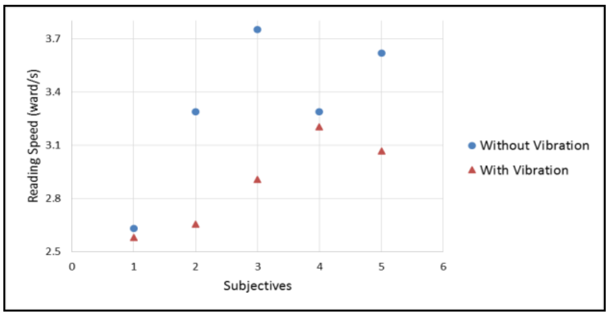
a_w (t_o) - Instantaneous frequency weighted acceleration obtained by using the running r.m.s. evaluation method

The Crest Factor is defined as the peak amplitude of a waveform divided by the RMS value.

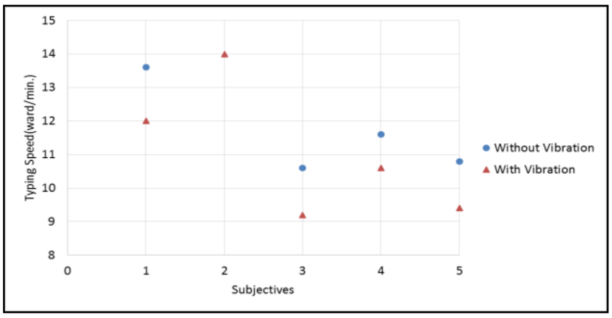
For the stastical analysis; Spearman ranked method, Pearson method and Wilcoxon signed rank method were used.

3. Results and Discussion

Figure 3 shows that the reading and typing speed of the passengers at two conditions: with vibration and without vibration.



(a)



(b)

Fig 3: Variation of (a) reading and (b) typing speed for 5 subjects

It is clear that the speed of reading and typing is higher when passengers are not exposed to vibration, compared to that with exposing to vibration. This difference was significant (0.001 Wilcoxon Signed Rank Test). Prashanth et.al (2013) [4] also found that reading activity is disturbed considerably due to vibration while travelling.

3.1 Whole body vibration

Root mean squared (RMS) value, Vibration dose value (VDV), Maximum transient vibration value (MTVV) and Crest factor (CRF), (fore vertical, fore-and-aft and lateral directions), were calculated for the whole body vibration exposure recorded with performing two activities (i.e., reading and typing).

3.1.1 Reading Activity

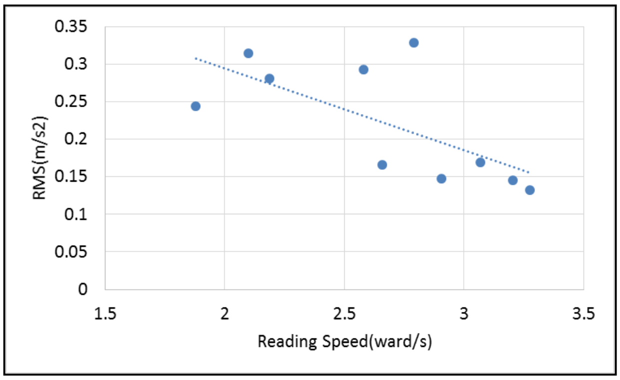
Table 1 shows the correlation coefficients between reading speed and vibration exposure of each parameters (i.e., RMS, Peak, Peak-Peak, VDV, MTVV and CRF) from Spearman rank method and Pearson method.

Table 1: Correlation Coefficient for Reading Activity

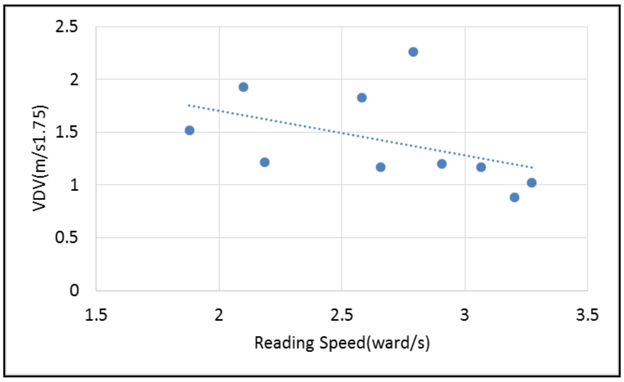
	Correlation Coefficient from Spearman Rank Method	Correlation Coefficient from Pearson Method
RMS-X	-0.442	-0.497
RMS-Y	-0.685	-0.671
RMS-Z	-0.515	-0.455
Peak-X	0.091	0.232
Peak-Y	-0.390	-0.084
Peak-Z	-0.200	-0.122
Peak-Peak-X	0.067	0.197
Peak-Peak-Y	-0.273	-0.144
Peak-Peak-Z	-0.212	-0.099
VDV-X	-0.018	0.032
VDV-Y	-0.705	-0.452
VDV-Z	-0.382	-0.321
MTVV-X	0.091	0.306
MTVV-Y	-0.382	-0.198
MTVV-Z	-0.527	-0.345

CRF-X	0.564	0.507
CRF-Y	0.661	0.639
CRF-Z	0.552	0.426

Table 1, clearly shows that RMS of fore-and aft vibration (y axis), VDV of Y axis and CRF-Y axis have the most dominant correlation with the reading speed. Figure 4 shows the correlation between reading speed and RMS and VDV.



(a)



(b)

Fig 4: Correlation between Reading Speed and (a) RMS value and (b) VDV value of Vibration exposure

Reading speed is significantly correlated with RMS of fore-and aft vibration (Y axis) and VDV of Y axis as shown in Figure 4. However, according to the Wang et.al (2006) [5], vertical vibration (Z axis) is the most dominant axis for vibration exposure.

3.1.2 Typing Activity

Table 2 shows the correlation coefficients between typing speed and vibration exposure of each parameters (i.e., RMS, Peak, Peak-Peak, VDV, MTVV and CRF) from Spearman rank method and Pearson method.

Table 2: Correlation Coefficient for Typing Activity

	Correlation Coefficient from Spearman Rank Method	Correlation Coefficient from Pearson Method
RMS-X	0.100	0.200
RMS-Y	-0.100	-0.041
RMS-Z	-0.100	-0.023
Peak-X	-0.200	0.028
Peak-Y	-0.200	-0.358
Peak-Z	-0.200	0.059
Peak-Peak-X	-0.200	-0.056
Peak-Peak-Y	-0.500	-0.368
Peak-Peak-Z	-0.200	0.066
VDV-X	0.100	0.159
VDV-Y	-0.100	-0.136
VDV-Z	-0.200	-0.013
MTVV-X	-0.200	-0.161
MTVV-Y	-0.500	-0.467
MTVV-Z	-0.200	-0.145
CRF-X	-0.500	-0.634
CRF-Y	-0.900	-0.879
CRF-Z	0.300	0.042

When considering the Spearman rank method and Pearson method as shown in Table 2, it is clear that CRF-fore and aft axis (Y axis) has the most dominant correlation with the typing speed. Figure 5 shows the correlation between typing speed and CRF.

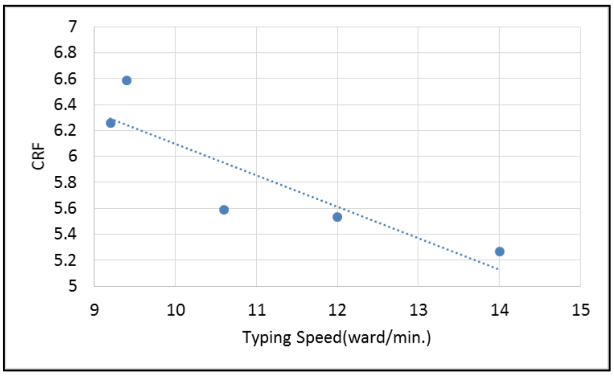


Fig 5: Correlation between Typing Speed and Crest Factor of Vibration exposures

Among three axis (XYZ) vibrations, fore-and aft vibration is most dominant and significantly correlated with typing speed as shown in Figure 5.

4. Conclusions

It was found the typing speed and the reading speed are significantly affected by vibration exposures. The speed of reading and typing is higher when the passengers were not exposed to the vibration, compared to that when the passengers were exposed whole body vibration.

Among three direction of vibration exposures (i.e. fore and aft, lateral and vertical), it is identified that the greater vibration exposure was in the fore and aft direction than the other two directions. It is desired to damp the vibration that comes in direction of fore and aft axis in order to increase reading speed and typing speed while travelling. Further studies with large number of passengers is required to proposed a relationship between vibration exposures and performances of two task, namely, reading and typing.

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