



AENSI Journals

Australian Journal of Basic and Applied Sciences

ISSN:1991-8178

Journal home page: www.ajbasweb.com



Vibration Magnitudes for Z-axis at the Pedal-pad on Tarmac and Paved Road Surface

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ARTICLE INFO

Article history:

Received 15 April 2014

Received in revised form 22 May 2014

Accepted 25 October 2014

Available online 10 November 2014

Keywords:

ISO 2631-1:1971; pedal-pad; road surface (tarmac and paved); frequency-weighting $r.m.s$ acceleration as function of time ($a_{r.m.s}$).

ABSTRACT

Vibration at the pedal-pad can contribute to discomfort of foot plantar fascia during driving. This experimental study is conducted to determine the root-mean-square ($r.m.s$) on z-axis or the vertical vibration magnitude for the three different sizes of pedal-pad on the two different road surfaces (tarmac and paved). ISO 2631-1:1997 was used for frequency-weighting (W_k) and frequency weighting $r.m.s$ acceleration as function of time ($a_{r.m.s}$) values calculated in one-third octave step with range of frequency 0.5 Hz to 80 Hz in vertical vibration. The finding of the study shows that the value of amplitude $a_{r.m.s}$ for small pedal-pad is higher compared with medium and large pedal-pads. For road surface, the paved road surface produced higher transmissibility vibration values for all three different sizes of pedal-pad as compared to tarmac road surface. The difference value of transmissibility for small pedal-pad is 0.036 ms^2 , whereas the medium pedal-pad is 0.027 ms^2 , and the large pedal-pad is 0.02 ms^2 .

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To Cite This Article: Ahmed Rithauddeen bin Yusoff, Baba Md Deros, Dian Darina Indah Daruis., Vibration Magnitudes for Z-axis at the Pedal-pad on Tarmac and Paved Road Surface. *Aust. J. Basic & Appl. Sci.*, 8(19): 214-217, 2014

INTRODUCTION

While the driver sits on the seat to drive a car, his feet interact with the pedal. Vibration will occur in the car when the car engine is turned on. It is transmitted to the mount, chassis, pedal, and then the foot plantar fascia. Vibration of foot plantar fascia may contribute to discomfort, annoyance, or interference with activities. The sensations come with varying strength according to the vibration magnitude, the vibration frequency, the direction of vibration, and the contact conditions with the vibration surface (Morioka, M., M.J. Griffin, 2010).

For the fore-and-aft, lateral, and vertical vibration at the feet, International Standard 2631-1 [ISO 2631-1 1997] uses frequency weighting W_k , while British Standard 6841 [BS 6841 1987] uses frequency weighting W_b . The differences between the two frequency weighting, W_b and W_k , have been explained by Griffin (1998). According to the standard (ISO 2631-1:1997), the frequency range considered is 0.5 Hz to 80 Hz for health, comfort and perception for back and feet of a seated person. Root-mean-square with frequency-weighted values calculated in 1/3 octave is to determine the average for quantities that fluctuate with time and variation in human sensitivity to vibration of different frequencies.

This study was primarily designed to examine the Root-Mean-Square Vibration Magnitude for three different sizes of pedal-pad on two different road surfaces (tarmac and paved). It is hypothesised that, whether three different sizes of pedal-pad by two different road surfaces (tarmac and paved) give effect to the vibration magnitude.

Experimental Procedure:

The vehicle used in this experiment is a popular Malaysian made compact car, with 3 cylinder DOHC engine and capacity 989cc. Signal vibration measurement is conducted at accelerator pedal. In this experiment, the researcher used three different sizes pedal pads.

Small pedal-pad refers to actual size of pedal pad which is used in one of the national car (Length: 8 cm and width: 3.5 cm). The other two pedal pads sizes increase in 2 cm for its length and 1.5 cm for its width. At the edge of the right side of the pedal pad there is an area to fix accelerometer of the size of 2 cm x 2 cm. The Pulse front-end frame model 3560 C with controller module type 7536 and 6 channel input module type 3039 by Bruel & Kjaer was used as a measurement tool. The Pulse front-end will be link with the Compaq laptop using

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Ethernet connection. The Pulse labshop version 14.0 software is used to analysis the data. Vibration was measured using a lightweight piezoelectric accelerometer.

The accelerometer used is model 751-100 isotron (uniaxial) by Endevco Corporation. The output sensitivity of accelerometer is 103.1 mV/g or 10.51mV/m/s². Super low-noise coaxial cable model AO-0038 and plug adaptor model BNC / 10 UNF by Bruel & Kjaer was used as connector between accelerometer to Pulse front-end. Additional tools used in this experiment were pocket inverter for convert 12 VDC power from car into 220 VAC power connections.

The experiment was conducted in Putrajaya area. Two subjects were involved in the experiment. One of the subjects drove the car and the other subject collected the data using the computer. The driver drove the car on two different road surfaces which are tarmac surface and paved road. The road surfaces are as shown in Figure 1.



Fig. 1: Road surfaces : (a) Highway, and (b) Pavement.

In order to measure the vibration, the experimental pedal-pad must be screwed and attached to the original pedal pad. A single-axis accelerometer was placed on the pedal-pad. A single-axis accelerometer measures vibration in vertical axis. The method of fixing the pedal and equipment is illustrated in Figure 2. The mounting of accelerometer on a clean flat surface and with proper torque or adhesives is crucial for proper vibration monitoring. Improper mounting of accelerometer onto the test structure can lead to both erroneous data and permanent damage accelerometer (Fouladi, M.H., 2011). The vibration signals were measured while driving on two different road surfaces with three different sizes of pedal-pads. The driver controlled the speed between the ranges of 30 km/h to 40 km/h manually. The experiment was conducted five times.



Fig. 2: (a) Set-up equipment inside the car, and (b) Accelerometer mounting of accelerometer on pedal tightened with the screw.

Data Acquisition:

The effective vibration analysis first begins with acquiring accurate time-varying signals from accelerometer. The raw analog signal is processed by Pulse Labshop version 14.0 software. In order to obtain the work-flow and data, the researcher has to setup at Pulse Labshop template which consist four important windows. The four windows are; configuration organiser, measurement organiser, function organiser, and display organiser. The time domain for signal-recording period was 32 second (512 samples per-second), delta time is 0.001953 second and number of samples collected (N) is 16384 samples. For frequency domain are delta frequency 0.03125 Hz, frequency range 0.03125 Hz to 200 Hz, and number of samples is 6401 samples. The raw data (*.txt file) for five time repeatability test will be mean for the measure $a_{r.m.s.}$.

RESULTS AND DISCUSSION

The purpose of this experiment is to determine r.m.s vibration magnitude of z-axis at three different sizes of pedal-pad using frequency-weighted root-mean-square acceleration as a function of time. The researcher also made a comparison between two different road surfaces which are tarmac and paved road surfaces. For the analysis, the researcher referred to ISO 2631-1:1997 for principal frequency weightings in one-third octave

(table 3 under clause 6), frequency-weighted acceleration (subclause 6.4.2) and frequency-weighted r.m.s acceleration as a function of time (time history) (subclause 6.1). The frequency-weighted of acceleration spectra is defined as in Eq. [1].

$$a_w = \left[\sum_i (w_i a_i)^2 \right]^{1/2} \quad (1)$$

Where a_w is the frequency-weighted r.m.s acceleration, in meters per second squared (ms^2). w_i is the weighting factor (W_k) for the i th one-third octave band and a_i is the r.m.s acceleration for the i th one-third octave.

The frequency-weighted r.m.s acceleration as a function of time (time history) is defined as in Eq. [2].

$$a_{r.m.s} = \left[\frac{1}{T} \int_0^T a_w^2(t) dt \right]^{1/2} \quad (2)$$

Where $a_{r.m.s}$ is the frequency-weighted r.m.s. acceleration as a function of time is expressed in metres per second squared (ms^2). $a_w(t)$ is the weighted acceleration as a function of time (time history), in metres per second squared (ms^2) and T is the duration of the measurement, in seconds.

Referring to Table 1, the value $a_{r.m.s}$ from small pedal-pad is higher as compared to medium and large pedal-pad for both road surfaces. On tarmac road surface, large pedal-pad $a_{r.m.s}$ is low as compared to the small and medium pedal-pad. It is shown that the large pedal-pad contributed less vibration stimulation to foot plantar fascia compared to the small pedal-pad, with only 0.002 ms^2 differences. On the other hand, for the paved road surface, the small pedal-pad shows at amplitude $a_{r.m.s}$ of 0.078 ms^2 which is highest compared to the medium and the large pedal-pad. The large pedal-pad contributed less vibration stimulation at foot plantar fascia, the difference $a_{r.m.s}$ between the small pedal-pad is 0.018 ms^2 and medium pedal-pad is 0.01 ms^2 .

Table 1: Result $a_{r.m.s}$

	Tarmac Road Surface (ms^2)	Paved Road Surface (ms^2)
Small Pedal-pad	0.042	0.078
Medium Pedal-pad	0.041	0.068
Large Pedal-pad	0.040	0.060

Figure 3 shows $a_{r.m.s}$ on two different road surfaces (tarmac and paved). The result shows the paved road surface contributed to a high amplitude $a_{r.m.s}$ value compared to tarmac road surface. The difference value for the three pedal pads between the tarmac road surface and the paved road surface are 0.036 ms^2 (small pedal-pad), 0.027 ms^2 (medium pedal-pad), and 0.020 ms^2 (large pedal-pad). The differences were most probably due to the different roughness index based on International Roughness Index (IRI). For the tarmac road surface is IRI 2.08 and for the paved road surface is IRI 5.46 (Daruis 2010).

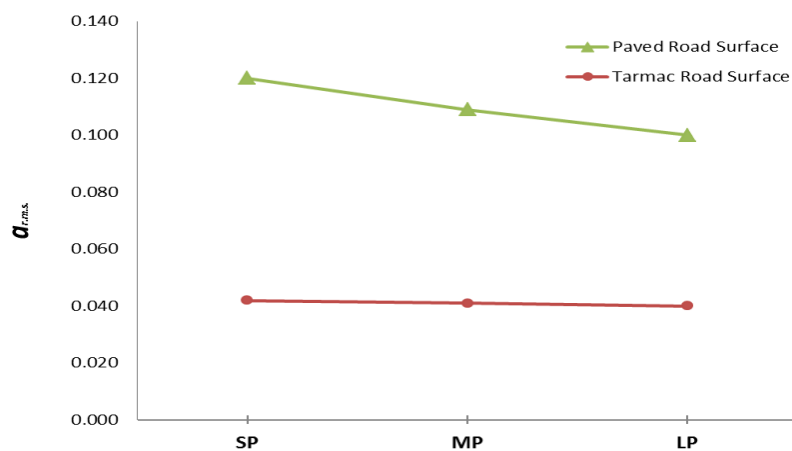


Fig. 3: $a_{r.m.s}$ on tarmac and paved road surface.

Conclusion:

Values of z-axis $a_{r.m.s}$ at the three different of sizes pedal-pad had been observed on tarmac and paved road surface. The result shows that the value of amplitude $a_{r.m.s}$ for small pedal-pad is higher compared to the medium and large pedal-pad. For the paved road surface with the three different sizes of pedal-pad contributed the high value of $a_{r.m.s}$ compared to the tarmac road surface. It can be concluded that the size of pedal-pad and the road surface can be influenced the vertical vibration. The bigger size of pedal-pad will reduce the $a_{r.m.s}$ and less human sensitivity. Moreover, the higher index of IRI will increase the $a_{r.m.s}$ and the transmissibility vibration from road surface to car body, pedal, and then to the foot plantar fascia.

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