Journal of the Society of Automotive Engineers Malaysia
Volume 3, Issue 1, pp 50-62, January 2019
e-ISSN 2550-2239 & ISSN 2600-8092

Foot-Transmitted Vibration: Automotive Accelerator Pedal-Pad Vibration on Tarmac and Paved Road

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ORIGINAL ARTICLE — ***Open Access***

Article History:

Received
24 Jun 2018

Received in revised form
11 Nov 2018

Accepted
14 Nov 2018

Available online
1 Jan 2019

Abstract – *Vibration at the pedal-pad may contribute to the discomfort of the foot plantar fascia during driving. In this study, the experiment is conducted using a "five-time repeatability" test of the same procedure and shall determine root-mean-square vibration magnitude and vibration transmissibility on Z-axis or vertical vibration magnitude for the three different sizes of pedal-pad on tarmac and paved surface. ISO 2631-1:1997 is used for frequency-weighting (Wk) in one-third octave step with a range of frequency 0.5 Hz to 80 Hz in vertical vibration. The analysis is divided into two; frequency-weighted acceleration and frequency-weighted root-mean-square acceleration on vibration magnitude; and vibration transmissibility. The result shows that small pedal-pads at a resonance frequency of 4 Hz and 10 Hz give high value on frequency-weighted acceleration compared to medium and large sized pedal-pads. The frequency-weighted RMS acceleration on the tarmac and paved road surfaces show that small pedal-pad also give high value compared to medium and large sized pedal-pads. The International Roughness Index shows that paved road surfaces affect frequency-weighted RMS acceleration differently, which is higher compared with tarmac. The vibration transmissibility result shows that the percentage pedal-pad effective amplitude transmissibility value on paved road surfaces is more than 100% compared with the tarmac road surface on three sizes of pedal-pads. A comparison of frequency-weighted RMS acceleration of pedal-pads and car bodies for three different sizes of the pedal-pad also show that the paved road surface contributes more vibration to pedal-pads compared with the tarmac road surface. It can, therefore, be concluded that the size of the pedal-pads and the type of road surface can influence foot-transmitted vibration.*

Keywords: Pedal-pad, road surface (tarmac and paved), foot-transmitted vibration, frequency-weighted acceleration, frequency-weighted root-mean-square

Journal homepage: www.journal.saemalaysia.org.my

1.0 INTRODUCTION

Drivers use their right foot to control the deflection of the accelerator pedal, which in turn controls the longitudinal dynamics of the car. Normally, to operate and control accelerator pedals, the heel rests on the floor of the car and the foot plantar fascia is in contact with the accelerator pedal-pad (Nishiyama et al., 2000). An accelerator pedal is a device which is used in many types of vehicles that allows an operator to control engine power remotely. Generally, it is paired with a brake pedal and sometimes a clutch, enabling a driver to control the speed of the vehicle almost exclusively with his feet. An accelerator pedal is typically connected directly to throttle either by using cables or electronically to a computer that could mechanically adjust the throttle based on pedal input.

Vibration occurs in a car when the engine is turned on and is then transmitted to the mounting, chassis, car-body parts (e.g. pedal) and eventually the human body (e.g. foot) (Douville et al., 2006; Yu et al., 2001; Duncan et al., 1996). Vibration increases when the vehicle is in a dynamic situation. This is caused by uneven road surface and change of vehicle velocity (Nahvi et al., 2009). The vibration also causes discomfort to the driver and passengers, but more so for the driver who operates and controls the vehicle. When there is vibration in the driver's compartment area, the driver may be distracted and lose focus while driving a vehicle.

When discussing the vibration that a driver or passenger experiences in a vehicle, it is important to consider the vehicle and human as a coupled dynamic system. In addition, there are usually a number of possible sources of vibration that can reduce the perceived comfort of car occupants. Two possible vibration sources are the road input at the tyre contact patches as well as the induced vibration from the power-train and ancillaries. The vibration from these sources is filtered by the structural dynamic transmission paths from the points of excitation to the pedal-pad, which is usually attached to the car-body or side of the engine room of the vehicle. The resultant vibration may be amplified in some frequency regions and attenuated in others, depending on structural resonance occurring in the transmission path. As a pedal-pad is constructed in different sizes, it can also result in additional modification of the vibration. Also, since the lower extremities can be modelled as a mechanical system consisting of masses connected by spring and dampers, the resultant transmissibility will also depend on the foot plantar fascia which is in contact with the accelerator pedal-pad – in particular, the size of the pedal-pad surface. Finally, the human sensitivity to vibration is a function of both frequency and direction. This should be taken into account when evaluating the measured vibration levels to determine perceived human comfort.

The vibration of foot plantar fascia may contribute to discomfort, annoyance, or interference with a driver’s activities, with the sensation varying in strength according to the vibration magnitude, the vibration frequency, the direction of vibration, and the contact conditions with the vibration surface (Morioka & Griffin, 2010). Studies conducted by researchers on vibration transmissibility have usually focused on vibration measurement objectives at the vertical axis (Hostens & Ramon, 2003; Griffin, 1990). According to Parsons et al. (1982), vertical vibration is more effective on the feet compared to horizontal vibration. Morioka and Griffin (2010) mentioned in their article that at frequencies less than 50 Hz, the foot is most sensitive to vertical vibration. The measurement of vertical vibration at the feet can be evaluated by two main standards, the International Standard 2631-1 (International Organization for Standardization, 1997) and the British Standard 6841 (Morioka & Griffin, 2010; British Standard Institution, 1987). For the vertical vibration at the feet, International Standard 2631-1 (International Organization for Standardization, 1997) uses frequency weighting Wk, while British Standard 6841 (British Standard Institution, 1987) uses frequency weighting Wb. The differences between the two frequency weightings, Wb and Wk, have been explained by Griffin (1998). According to the ISO 2631-1:1997 standard (International Organization for Standardization, 1997), a frequency range of 0.5 Hz to 80 Hz is considered ideal for the perceived health and comfort of a person's back and feet while seated. The vibration magnitude is quantified by its displacement (m), its velocity (m/s), or its acceleration (m/s^2). For practical convenience, the vibration magnitude is expressed in terms of an average measure of the acceleration, usually the root-mean-square value (m/s^2 RMS). The RMS magnitude is related to the vibration energy and thus the vibration injury potential. The frequency of vibration is expressed in cycles per second and it is measured in Hertz (Hz). Root-mean-square with frequency-weighted values calculated at one-third octave is used to determine the average for quantities that fluctuate with time and vary in human sensitivity to vibration of different frequencies.

Nishiyama et al. (2000) in their article mentioned that the vibration transmissibility on the driver occurs when the hand grips the steering wheel, and the driver sits and rests on the vehicle seat while the lower extremity controls and operates the pedals. The reason for the disparity in response is due to the distinct dynamic characteristics or different "transmissibility" of the pedal-pads. The isolation efficiency of pedal-pads can be determined using the PEAT value. The PEAT value calculation is similar to the SEAT value ("seat effective amplitude transmissibility"), but the differences lie in the input point and output point.

Since there is a lack of studies on foot-transmitted vibration from pedal acceleration, it is worthwhile to conduct a study on this issue. Therefore, the two main objectives of this research are to determine whether two specific factors contribute to foot discomfort in dynamic conditions. First, to study pedal-pad designs to examine the root-mean-square vibration magnitude for three different pedal-pad sizes according to the two different road surfaces (tarmac and paved). Second, to identify the relationship between vibration transmissibility to the three different pedal-pad sizes on the tarmac and paved road surfaces.

2.0 METHODOLOGY

2.1 Apparatus

The vehicle used in this experiment is a popular Malaysian-made compact car, with a three-cylinder DOHC engine and 989cc capacity. The vibration measurement signal is conducted at the accelerator pedal. In this experiment, three different pedal-pad sizes made from steel plate grade SS400 are used, as shown in Figure 1.

A small pedal-pad refers to the actual pedal-pad size, which is currently used in one of the national cars (eight centimetres (cm) in length and 3.5 centimetres in width). The other two pedal-pad sizes increase by 2 cm in length and 1.5 cm in width (medium pedal-pad size is 10 cm x 5 cm and large pedal-pad size is 12 cm x 6.5 cm). At the edge of the right side of the pedal-pad, there is an area to affix an accelerometer which is 2 cm x 2 cm in size as shown in Figure 1. The Pulse front-end frame model 3560 C with controller module type 7536 and 6-channel input module type 3039 by Bruel & Kjaer, is used as a measurement tool. The Pulse front-end will be linked to a Compaq laptop by Ethernet connection. The Pulse Labshop version 14.0 software is used to analyse the data. Vibration is measured using a lightweight piezoelectric accelerometer.

The accelerometer model used is a 751-100 isotron (uniaxial) developed by Endevco Corporation. The output sensitivity of the accelerometer is 103.1 mV/g or 10.51mV/m/s^2. Super low-noise coaxial cable model AO-0038 and plug adaptor model BNC / 10 UNF (by Bruel & Kjaer) are used as connectors between the accelerometer to the Pulse front-end. Additional tools used in this experiment are pocket inverters to convert 12 VDC power from the car into 220 VAC power connections.

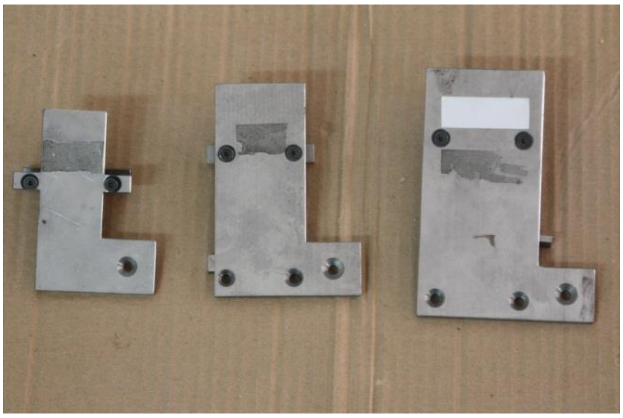

Figure 1: Three different sizes of pedal-pads

2.2 Procedures

The experiment is conducted within the area of Putrajaya, Malaysia. Two subjects are involved in the experiment. One of the subjects drives the car while the other subject collects the data using the computer, as shown in Figure 2. The driver drives the car on the two different road surfaces (tarmac and paved). The tarmac road surface is smooth as a highway. The highway has a flat, smooth surface with occasional unevenness which results in minimum disturbance. The IRI for tarmac road surfaces is 2.08 (Daruis et al., 2010; Nahvi et al., 2009). Paved road surfaces are characteristically roads consisting of small cobblestones. The paved road is essentially a cobbled street made of similar smooth stones of 5-mm thickness and an IRI of 5.46 (Daruis et al., 2010; Nahvi et al., 2009). The examples of road surfaces are as shown in Figure 3.

To measure the vibration, the experimental pedal-pad is screwed and attached to the original pedal pad. A single-axis accelerometer is placed on the pedal-pad and car-body. A single-axis accelerometer measures vibration in Z-axis. The method of fixing the pedal-pad and equipment is illustrated in Figure 4. The accelerometer mounting is a clean, flat surface with proper torque or adhesives which are crucial for proper vibration monitoring. Improper mounting of an accelerometer onto the test structure can lead to both erroneous data and permanent damage to the accelerometer (Hosseini et al., 2011). The vibration signals are measured while driving on two different road surfaces with three different pedal-pad sizes. The driver manually controls the car speed between 30 km/h to 40 km/h. The same experiment is repeated five times.

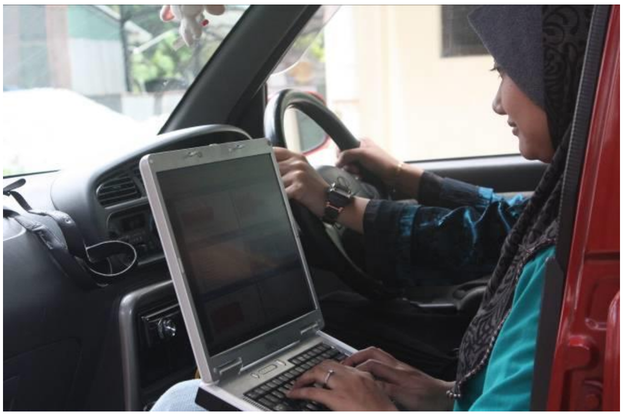

Figure 2: Data is collected by the subject

(a) **(b)**

Figure 3: Type of road surfaces **(a)** Highway (tarmac), and **(b)** Pavement

Figure 4: The method of affixing the equipment.

The accelerometer must be calibrated before and after taking the measurement. The purpose of calibration is to provide enhanced performance by improving the overall accuracy of the underlying sensors and to avoid erroneous data. The accelerometer is calibrated with a

Bruel & Kjaer type 4294 Calibration Exciter (frequency: 159.2 Hz, RMS acceleration: 10 m/s^2, RMS velocity: 10 mm/s, RMS displacement: 10 µm). If the accelerometer is successfully calibrated, the result is indicated by a green bar as shown in Figure 5.

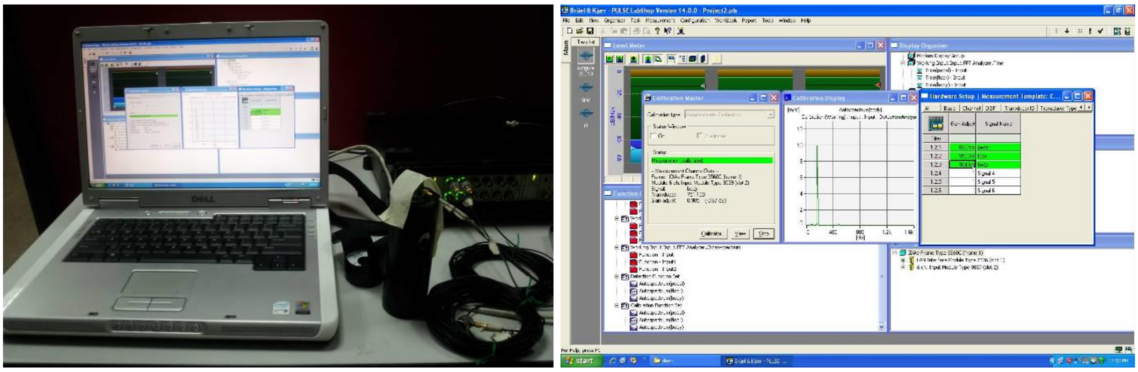

Figure 5: The method and result of calibration accelerometer

The effective vibration analysis begins with acquiring accurate time-varying signals from accelerometer. The raw analogue signal was processed by Pulse Labshop version 14.0 software. In order to obtain the work-flow and data, the researcher has to set up Pulse Labshop template which consists of four important windows, comprising configuration organizer, measurement organizer, function organizer, and display organizer (Figure 6). The time domain for the signal-recording period was 32 second (512 samples per second), delta time is 0.001953 second and the number of samples collected (N) is 16384 samples. For frequency domain are delta frequency 0.03125 Hz, in sampling frequency range 0.03125 Hz to 200 Hz, and the number of samples is 6401 samples.

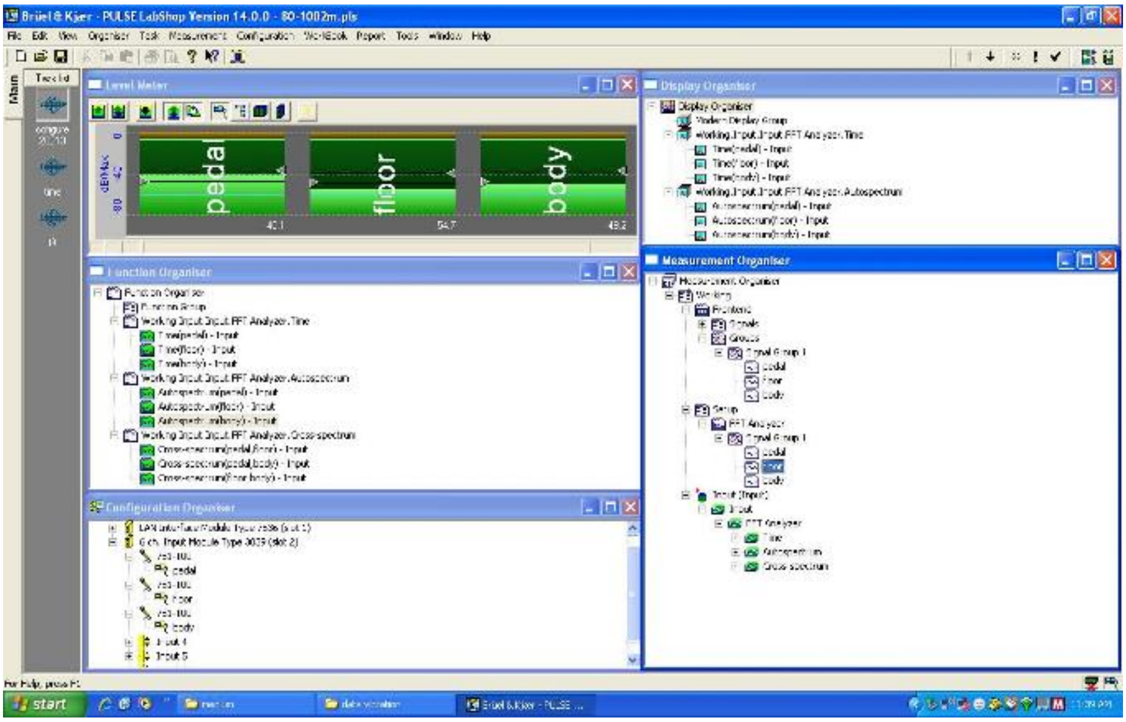

Figure 6: Four windows

3.0 DATA ANALYSIS

3.1 Root-Mean-Square Vibration Magnitude

The purpose of this experiment is to determine RMS vibration magnitude of Z-axis with three different sizes of pedal-pads using frequency-weighted root-mean-square acceleration as a function of time. A comparison between the two different road surfaces of tarmac and paved roads is made. For the analysis, ISO 2631-1:1997 (International Organization for Standardization, 1997) is referred to for principal frequency weightings in one-third octave (Table 3 under Clause 6), frequency-weighted acceleration (Subclause 6.4.2), frequency-weighted RMS acceleration (Subclause 6.1), and Crest Factor (Subclause 6.2.1). Morioka and Griffin (2010) refer to International Standard ISO 2631-1:1997 (International Organization for Standardization, 1997) for frequency weighting (W_k) of vertical vibration at the foot for seated persons. Statistical analysis is applied to determine the different IRI on the two road surfaces against the vibration of pedal-pads.

Before conducting data analysis, the most important thing the researcher has to do is to ensure the raw data are included into m/s^2 unit. The raw data gained from *.txt files are auto spectrum data in the $(m/s^2)^2$ unit. The raw data must be converted to RMS data in the m/s^2 unit. The frequency-weighted acceleration is defined in equation (1).

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

Where a_w is the frequency-weighted acceleration in meters per second squared (m/s^2), w_i is the weighting factor (W_k) for the ith one-third octave band and ai is the RMS acceleration for the ith one-third octave.

The frequency-weighted RMS acceleration is defined as shown in equation (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 RMS acceleration, it is expressed in metres per second squared (m/s^2). $a_w(t)$ is the weighted acceleration as a function of time (time history) in metres per second squared (m/s^2) and T is the duration of the measurement, in seconds.

Mathematically, Crest Factor (CF) can be expressed as equation (3).

$$CF = \frac{\max(a_w)}{a_{r.m.s}} \quad (3)$$

With the vibration of CF below or equal to nine, the frequency-weighted RMS acceleration is normally sufficient.

Statistical analysis of the frequency-weighted acceleration data is used to determine the difference of IRI between the tarmac and paved road surfaces about the vibration of pedal-pads. However, due to data not normally distributed (Shapiro Wilks' W, $P < 0.05$), the non-parametric test is used in the statistical analysis. The frequency-weighted acceleration on independent pedal-pads is examined using Mann-Whitney U tests.

3.2 Vibration Transmissibility

The purpose of this experiment is to identify vibration transmissibility from a car-body to pedal-pad. The PEAT method as well as the analysis, is similar to SEAT (Niekerk et al., 2003; Griffin, 1990). PEAT value can be calculated as root-mean-square (RMS) of the frequency-weighted acceleration.

PEAT$_{r.m.s}$ is the ratio of the frequency-weighted RMS acceleration on the pedal-pad ($r.m.s_{pedal\text{-}pad}$) to the frequency-weighted RMS acceleration of the car-body ($r.m.s_{car\text{-}body}$). Thus, the ratio PEAT as a percentage is defined in equation (4).

$$PEAT_{r.m.s.}(\%) = \frac{r.m.s._{pedal-pad}}{r.m.s._{car-body}} \times 100\% \tag{4}$$

This equation applies when the $r.m.s_{pedal\text{-}pad}$ is the frequency-weighted acceleration on the surface of the pedal-pad, and $r.m.s_{car\text{-}body}$ is the frequency-weighted acceleration at the base of the pedal-pad. From this result, a PEAT value of 100% indicates that the dynamic properties of the pedal-pad have not improved or reduced the ride comfort of the pedal-pad. If the PEAT value is greater than 100%, it indicates that the ride is worse in the pedal-pad than on the car-body. And a PEAT value of less than 100% indicates that dynamic properties of the pedal-pad are effective in reducing the vibration.

4.0 RESULT AND DISCUSSION

4.1 Frequency-weighted Acceleration and Root-Mean-Square Vibration Magnitude

Vibration for three different sized pedal-pads and two road surfaces are determined at each frequency in vertical vibration. With reference to a_w in equation (1), the graph in Figure 7 is developed according to the size of the pedal-pad to identify the trend frequency-weighted acceleration with 23 preferred one-third octave frequencies between 0.5 Hz to 80 Hz. Figure 7 shows a frequency between the ranges of 3.156 Hz to 12.5 Hz in which each one-third octave presents a spiny trend.

Referring to Figure 7, within the frequency resonance range of 4 to 10 Hz, there are two higher peaks that rise when compared with other peaks. The highest peak is in the frequency resonance of 10 Hz followed by the second peak in frequency resonance 4 Hz for all three sizes of pedal-pads on two road surfaces. For the first peak, which is at frequency resonance 10 Hz, the small pedal-pads show the highest sensitivity (paved road surface: 0.12 m/s^2 and tarmac road surface: 0.051 m/s^2) on foot plantar fascia compared to the medium and large pedal-pads. Large pedal-pads show the lowest sensitivity (paved road surface: 0.064 m/s^2 and tarmac road surface: 0.040 m/s^2) on foot plantar fascia.

For the second peak at frequency resonance 4 Hz, the result shows that the small pedal-pad contributed the highest vibration sensitivity on foot plantar fascia compared to the medium and large pedal-pads. Amplitude frequency-weighted acceleration for small pedal-pads on road surface tarmac is 0.0867 m/s^2 and 0.04986 m/s^2 on paved. Large pedal-pads show the lowest vibration sensitivity compared to medium pedal-pads where amplitude frequency-weighted acceleration for large pedal-pads on tarmac road surfaces is 0.03605 m/s^2 and for a paved road the surface is 0.0459 m/s^2. From the result of the experiment, all the three graphs show vibration sensitivity for the small pedals to be the highest at foot plantar fascia when at peak frequency resonance 4 Hz and 10 Hz, followed by medium pedal-pads and the lowest being the large pedal-pads.

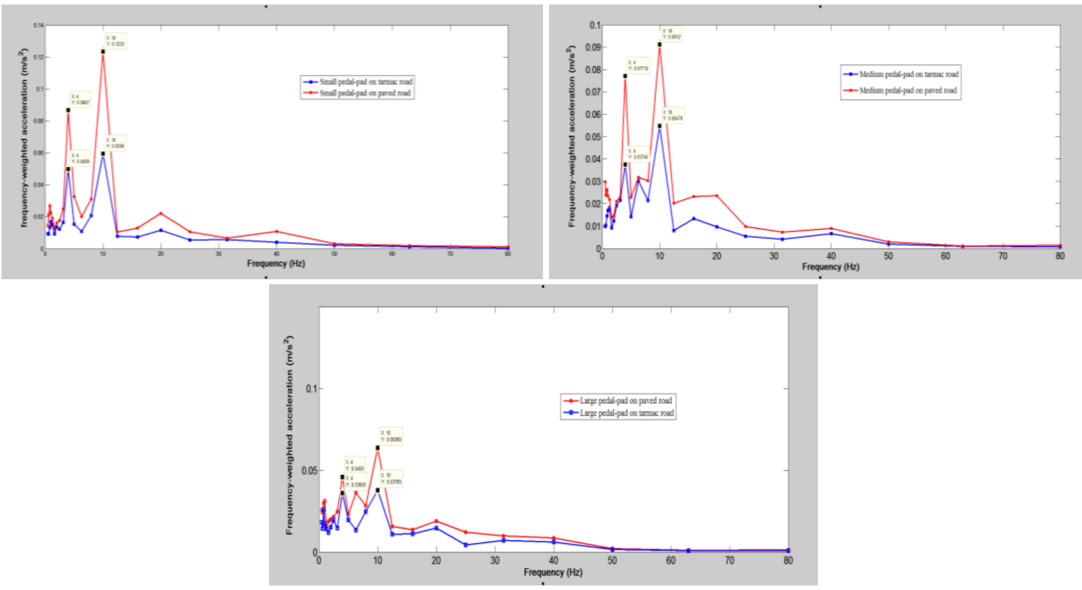

Figure 7: Trend frequency-weighted acceleration with 23 preferred one-third octave frequencies between 0.5 Hz to 80 Hz

After a peak of 10 Hz, the frequency resonance of foot plantar is the least sensitive to vertical vibration at 12.5 Hz. One-third octave step range between 12.5 and 50 Hz is more sensitive on foot plantar fascia.

To determine the difference between three pedal pad sizes and the two road surfaces, the frequency-weighted RMS acceleration should be taken into account. Frequency-weighted RMS acceleration is a method of determining the average for quantities that fluctuate with time about a central value. Under sub-clause 6.2.2 of the ISO 2631-1:1997, if the CF is below or equal to nine, the method of frequency-weighted RMS acceleration is normally sufficient. To acquire value $a_{r.m.s}$ from equation (2), value a_w should be taken into account. Table 1 illustrates the result for $a_{r.m.s}$ and CF for each size of pedal-pad on two road surfaces.

Table 1: Value of frequency-weighted RMS acceleration as a function of time and Crest Factors

	Tarmac Road Surface (m/s^2)		**Paved Road Surface (m/s^2)**	
	$a_{r.m.s}$	CF	$a_{r.m.s}$	CF
Small Pedal-pad	0.042	1.42	0.078	1.12
Medium Pedal-pad	0.041	1.18	0.068	1.34
Large Pedal-pad	0.040	0.99	0.060	1.15

Referring to Table 1, the value $a_{r.m.s}$ from small pedal-pads is the highest compared to medium and large pedal-pads for both road surfaces. On the tarmac road surface, large pedal-pad $a_{r.m.s}$ is the lowest compared to small and medium pedal-pads. The large pedal-pad contributes less vibration stimulation to foot plantar fascia compared to the small pedal-pad, with only a 0.002 m/s^2 difference. On the other hand, for the paved road surface, the small pedal-pad has an amplitude $a_{r.m.s}$ of 0.078 m/s^2, which is the highest compared to the medium and the large pedal-pads. The large pedal-pad contributes less vibration stimulation at foot plantar fascia. The $a_{r.m.s}$ difference between small pedal-pads is 0.018 m/s^2 and medium pedal-pads is 0.01 m/s^2.

In terms of IRI and vibrations of the three different sizes of pedal-pads, there is a difference (Mann-Whitney, $P<0.05$) between the two road surfaces. For the tarmac road surface, IRI is 2.08, and for the paved road surface, IRI is 5.46.

Table 2 shows the IRI value mean rank for paved road surfaces is 81.20, which is higher than the IRI value mean rank for tarmac roads at 57.80. It can be concluded that the higher the IRI, the higher the amplitude frequency-weighted RMS acceleration. The increasing of amplitude frequency-weighted RMS acceleration increases the sensitivity of foot plantar fascia when it comes into contact with pedal-pads. Nahvi et al. (2009) in his research states that if there is an increase in IRI, it can cause increased kurtosis value and vibration dose value. This causes the driver and passenger to feel discomfort while in the vehicle.

Table 2: The mean rank of different types of road surface

Road Surface	International Roughness Index (IRI)	Mean Rank
Tarmac	2.08	57.80
Paved	5.46	81.20

4.2 Vibration Transmissibility

4.2.1 PEAT Value

PEAT values are calculated using the frequency-weighted acceleration. The result in Figure 8 illustrates vibration transmission from car-body to pedal-pad in the form of percentages value. The difference in the transfer of vibration from car-body to the pedal-pads exists in two different road surfaces. From the result base on equation (3), transmissibility ratio data was obtained and it was converted to percentage values.

Figure 8 demonstrates that a paved road surface contributes to a higher percentage value compared to a tarmac road surface. For a paved road surface, the percentage value is more than 100%. If PEAT value is greater than 100%, this indicates that there is worse vibration transmission in the pedal-pad than in the car-body. As for sizes of pedal-pads on a paved road surface, small sized pedal-pads contribute the highest percentage value (144%), followed by medium and large-sized pedal-pads (111%). From the results, it can be concluded that small pedal-pads experience the worst vibration transmission on the car-body compared to medium and large sized pedal-pads.

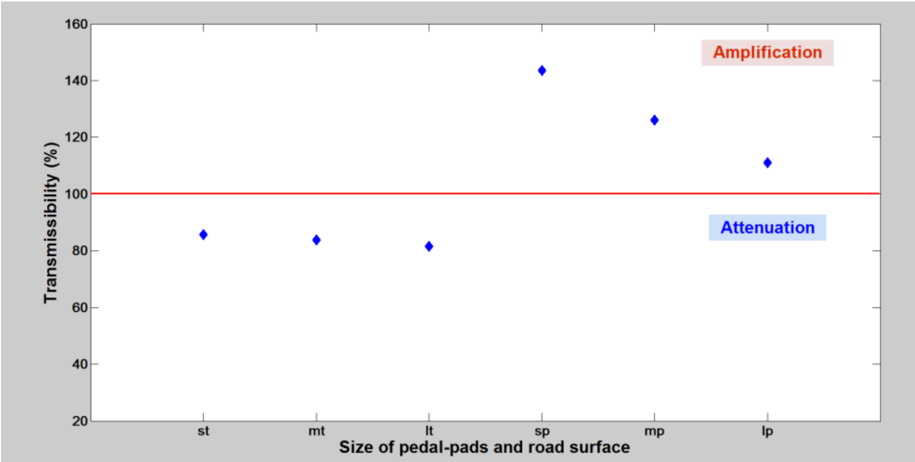

Figure 8: Percentage of transmissibility vibration from car-body to pedal-pad based on the size of pedal-pads and road surface

Tarmac road surfaces show the percentage value is less than 100%. This is caused when driving on the tarmac road surface, whereby transfer of vibration due to road surface friction between the tires can reduce the transfer of vibration from the car-body to pedal-pad. The dimension sizes of the small pedal-pads give a higher percentage value of 85.63% as compared to medium and large pedal-pads. Large pedal-pads provide a low percentage value of 81.60%. This indicates that small pedal-pads transfer more vibration from the car-body compared with medium and large pedal-pads.

4.2.2 Comparison Frequency-Weighted RMS Acceleration Between Pedal-Pad and Car-Body PEAT Value

Figure 9 shows comparison of frequency-weighted RMS acceleration of pedal-pads and car-body for three different sizes of pedal-pads (small, medium, and large). The 45-degree diagonal line starting at the origin is used to separate two areas of comparison, frequency-weighted RMS acceleration for pedal-pads and car-body. The frequency-weighted RMS acceleration values above the linear line show vibration on pedal-pads is greater than car-body.

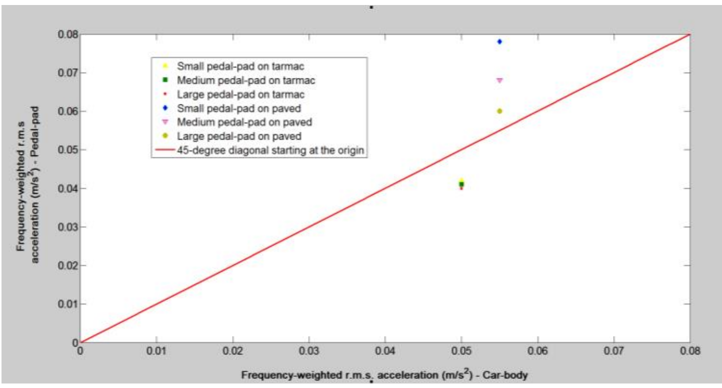

Figure 9: Comparison frequency-weighted RMS acceleration of pedal-pads and car-body for three different sizes of pedal-pads (small, medium, and large)

Referring to Figure 9, the result for paved road surfaces shows that the frequency-weighted RMS acceleration values for three of the pedal-pads are above the 45-degree diagonal line. This means that the vibration for three sizes of pedal-pads is greater than that of the car-body. The highest point for the small pedal-pad is 0.078 m/s^2, while 0.060 m/s^2 is the lowest point for the large pedal-pad.

For driving on tarmac road surfaces, the data shows the frequency-weighted RMS acceleration value for three of the pedal-pads below the 45-degree diagonal line. Small pedal-pads contribute to the highest point which is 0.042 m/s^2 followed by the medium and large pedal-pads where the point value for large pedal-pads is 0.040 m/s^2.

5.0 CONCLUSION

When the plantar fascia interfaces with the pedal-pad which is a vibrating surface, frequency weighted RMS acceleration at the three different sizes of pedal-pads are observed with their Z-axis vibration on the tarmac and paved road surfaces. The result shows that there are two higher peaks compared to the other peak within the range of 0.5 Hz to 80 Hz where the frequency resonance is 4 Hz and 10 Hz. Small pedal-pads contribute to the highest value amplitude frequency-weighted acceleration at frequency resonance 4 Hz and 10 Hz. The large pedal-pads contribute to the lowest value frequency-weighted acceleration at frequency resonance 4 Hz and 10 Hz. The value of frequency-weighted RMS acceleration demonstrates that small pedal-pads obtain the highest value on the tarmac and paved road surfaces compared with medium and large pedal-pads. Referring to IRI for two different road surfaces, the mean value for the paved road surface is higher than the tarmac road surface. It can be concluded that the size of pedal-pad and the road surface can influence the foot-transmitted vibration. The larger sized pedal-pads reduce the frequency-weighted RMS acceleration and less foot sensitivity. Moreover, the higher index of IRI will increase the amplitude of frequency-weighted RMS acceleration.

On the transmissibility vibration from car-body to pedal-pad, it shows that the percentage PEAT value on paved road surfaces is more than 100% compared with tarmac road surfaces on three sizes of pedal-pads. For comparison, frequency-weighted RMS acceleration of pedal-pads and car-body for three different sizes of pedal-pad show that the paved road surface contributes more vibration to pedal-pads compared to the tarmac road surface. The finding reveals that transmissibility vibration from car-body to pedal-pad on paved road surfaces is amplified, or it gives more sensitivity to foot plantar fascia during an interface with the surface of pedal-pads.

It can be concluded that pedal-pad size plays an important role in the pedal element designs in terms of vibration transfer from the road surface to car-body, pedal, and then to the foot plantar fascia, particularly to provide comfort to the driver while driving. It is proven that small sized pedal-pads contribute the strongest vibration transfer compared to the medium and large sizes of pedal-pads. Since this research is focused only on sizes of pedal-pad and road surfaces, further research should be conducted using various types of pedal-pad material, whether it can influence the vertical vibration to the sensitivity of foot plantar fascia during operation and handling the acceleration pedal.

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