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Analysis of a Sedan Car Seat Vibration

M. R. Roslan[1], G. Priyandoko[2]
[1]Faculty of Mechanical Engineering, University of Malaysia Pahang, Pekan, Malaysia
[2]Department of Electrical Engineering, Faculty of Engineering, University of Widyagama, Malang, Indonesia
Email: gigih@widyagama.ac.id

ABSTRACT

Ride comfort in vehicle transportation is quite complex, and it depends on various dynamic performance criteria and subjective perception from the car passengers. Vibration discomfort from various factors such as vehicle conditions, the speed of the vehicle, road surface condition, vehicle load, and operating condition can lead to poor ride comfort. The driver seat will be the main part of a car that needed to get a dynamic comfort. Comfort and safety are major factors that need to be considered. To ensure the safety for passenger, the driver must feel comfortable while driving. The objective of this project is to analyze the vibration at the seat of a Proton Wira at different speeds, different loads and different road surfaces. In this project, use six different speeds. Vibration data from three types of road, they are tar road, yellow line road, and dirt road. Three different loads used for a car are collected using two accelerometers sensor that place on the driver seat and seat frame. The rough surface will cause a car to generate more vibration. The results for frequency and time responses show that the vibration increases at the dirt road. Transmissibility results for each speed and each load on the tar road, yellow line road and dirt road is calculated. Transmissibility at speed 80 km/h for load 3 achieved the highest value 1.54. Lowest value can be found at load two at speed 30 km/h that is 1.06. Comfort index for all speed is not uncomfortable for the tar road profile. Comfort index for all speed is not uncomfortable and a little uncomfortable for yellow line road profile. Comfort index for all speed is not uncomfortable, a little uncomfortable and fairly uncomfortable for yellow line road profile. Comfort index for all speed is a little uncomfortable and fairly uncomfortable for dirt road profile.

Keywords vibration, car seat, ride comfort, automotive.
Paper type Research paper

INTRODUCTION

Typically, vehicle purchases are driven by consumer requirements such as stability, functionality, safety, luxury, comfort, cost, and performance. The consumers' perspectives on the fulfillment of these requirements are often based on personal perceptions. Nowadays, with the increasing of the style design, model and smoothness of the car among the manufacturers it would be the big tough competition in the industry. These brand or the automotive manufactures that created the best requirement consequently get more profitable.

The main requirement that purchased by the passenger are the passenger seat comfort depends on both static and dynamic comfort. Static comfort defined by refers to the comfort of the vehicle owner when the vehicle is stationary. It can see when the potential customer tries or seated on the car seat during the showroom event. By sitting in the vehicle, it will be the best impression for the customer to feel the styling of the car and also a tactile experience — besides, the comfortable seat necessary the minimum muscular effort from the driver or passenger to maintain their seated position. The muscular fatigue also will minimize; it is because of the body contact with the seat, seatback, and floor enough to support [1].

Also, the noise, vibration, and harshness (NVH) during driving are characterized by dynamic comfort. The automotive manufacturers try hard to improve brand identity, customer loyalty, and perceived quality by taking important the interior sound the passenger [2]. The vibration will transmit to the body through the seat. Therefore the response of the human body to vibration also the seat's dynamic comfort was determined. Other than that, the vibration can cause noise.

The vibration measurement on the top car seats by applied the method base on ISO 2631 to determine the dynamic comfort [3]. Therefore, this experiment also showed the same method to analyze the vibration on the car seat of Proton Wira. The seat-pad accelerometer was used to measure the vibration at the seat driver or passenger interface. The objective measures consisted of the weighted root mean square (rms) acceleration measured at the set-top for a specific vibration input at the base of the seat according to ISO 2631 and an empirically derived ride number. Besides, this experiment also how the vibration effected by the three main vibration sources; the weight of the driver, different speed of the vehicle and road conditions.

In Malaysia, no ride comfort assessment could determine the quality of the car seat. The ride comfort assessment is important in order to monitor and maintain good services provided by the car manufacturer to the customer. Current car seat technology has too much vibration so it can cause discomfort to both driver and passenger. This vibration can affect the pregnant women, a person with back pain, old people and infant. This experiment is designed to identify how much vibration that will be produced on the Malaysian car seat due to three main vibration sources; the weight of the driver, different speed of the vehicle and road conditions. The objective of this project is to experiment with the car seat of a Proton Wira to get the reading on the vibration data produced using DasyLab software. From the data obtained, the analysis is made on the vibration caused by the weight of the driver, different speed of the vehicle and also road condition.

VIBRATION ANALYSIS

Vibration is oscillatory motion. The extent of the oscillation determines the magnitude of the vibration, and the repetition rate of the cycles of oscillation determines the frequency of the vibration [4]. The level of vibration in the vehicle is major influences on the perception and comfort in rail travel in comparison with another medium of transport [5]. Moreover, according to the free vibration known as natural vibration which the object that vibrates under its free natural condition such as simple classical pendulum as an example [6].

Other than that, according to although road surface lines generate vibration, there are differences between car and road vibration characteristic [7]. As usually when the magnitude of vibration is increased, there is a possibility of increasing discomfort. Besides, at low frequencies, the force that acts on the human body is proportional to the input of acceleration transmitted to the human body. Also, the exposure of standing passenger from vibration magnitude at the floor may cause discomfort and magnitude-dependence of discomfort caused by lateral vibration at frequencies between 0.5 Hz and 16Hz [8]. Cause of that the Whole Body Vibration (WBV) will effects the human at best may be discomfort and interference with activities at worst maybe injury or diseases [9]. Vibration could also cause blurred vision, loss balance of body, and poor concentration [10]. Sometimes, frequencies and vibrating surfaces might cause permanent damages to an internal organ; it is because each of the organs in the human body has their resonance frequency.

A. Transmissibility

The transmissibility of the seat will advise us those self-destructive considerations and conduct of the situated in separate road condition with different frequency inputs. Transmissibility varies as frequency changes. The work is an attempt towards studying dynamic characteristics of the passenger seat for comfort through objective evaluation. For objective evaluation, the transmissibility and ride comfort Index were found based on three different conditions on three different loads with six different speed. For better understanding, the vibration transmissibility key points taken for analysis are transmissibility values at different conditions and comfort index as per ISO 2631 for different conditions as shown in Table 1. The term seat transmissibility is used to quantify the vibration isolation efficiency of the car seat. It is the ratio of vibration at the top of the seat to the vibration at the frame [1]. The equation of transmissibility is equal to vibration at the seat divided by vibration at the frame.

TABLE I. ISO 2631-1 (1997) INTERNATIONAL STANDARD, HUMAN SENSITIVITY TO EXTERNAL VIBRATION IS BETWEEN 0.1HZ TO 80HZ [13]

RMS acceleration (m/s^2)	Comfort Index
Less than 0.315	Not Uncomfortable (NU)
0.315 to 0.63	A little uncomfortable (LU)
0.5 to 1	Fairly uncomfortable (FU)
0.8 – 1.6	Uncomfortable (U)
1.25 to 2.5	Very uncomfortable (VU)
Greater than 2	Extremely uncomfortable (EU)

B. Ride Comfort Index

Comfort can be described as a source of delight or expectation, and so give a sense of well-being [1]. A growingly demand to produce a vehicle that is enjoyable for the occupant made the manufacturers try to find ways to improve vehicle comfort for occupant expectation. Ride comfort is a dynamic performance characteristic of a railway vehicle, and it is affected by various factors such as temperature, noise, humidity, smell, and visual stimuli and vibrational but it is difficult to consider all factors simultaneously. Other than that, comforts also is a state of being relaxed and feel freedom from worry or disappointment, the act of consoling, giving relief in affliction. Many new methods have been proceeding to meet customer demand. Ride comfort symbolized an overall comfort and well-being of the vehicle’s occupant when the vehicles travel. Comfort is the lack of discomfort recommended by the research of the human body ride comfort [11].

Besides, seating dynamics, particularly the human perception of the dynamic comfort of a seat, is an area that is of expanding significance to automotive producing catering for a market becoming more and more competitive and experienced. A crucial part of the vibration experienced by the occupants of an automobile enters the body through the seat. To date, significant attention has been paid to the static comfort of seats while work on dynamic seat comfort is limited [1]. Separated starting with contamination and performance, economy, safety, and comfort are major factors to consider. The comfort of the driver plays a vital role in passenger safety, tiredness during a long drive, and driving in heavy traffic. Furthermore, comfort means an absence of any discomfort [12].

C. Whole Body Vibration (WBV)

The WBV involves the transmission of mechanical vibration to the human body in postures of standing with the frequency of concern ranging from 0.1 Hz to 80 Hz [13]. WBV would occur to the human if they were exposed to the shaking surface that supported their body where the vibration is come from the equipment then transmits to the human. For example, the vibration produced from the car due to poor traveling track and poor maintenance of suspension of the car will be transmitted from the vehicle through the seat where the human is supported. The vibration then will transmit to the body and the head. WBV can affect comfort, health, and efficiency depending on exposure time, amplitude and type of waveform. Frequency ranges from 0.1 to 80 Hz are most common to whole vibration study.

Also, intense occupational WBV exposure stemming from engines and vehicle has long been recognized as a contributor to early and accelerated spine disease and back pain [14]. Accordingly, measurement of WBV should be conducted on the surface transmitting vibration to the human. This because the level of vibration depends on the amount of viscous damping, structural damping of material and energy dissipation of dry friction between surface [15]. Figure 2.2 shows the sitting position of whole body vibration. There are also safety concerns associated with WBV, vibration frequencies which match the resonant frequency of the body have been shown to hamper a worker's ability to perform job tasks [16].

In a vehicle perspective, we cannot neglect vibrational source from various aspect as a major factor that contributes to discomfort on vehicle passenger. According to [1] when the magnitude of vibration is increased, there is usually an increase in discomfort. The vibration toward the body is dependent on body posture. The effects of vibration are complex.

METHODOLOGY

The test vehicle was a mid-size Malaysian executive vehicle, Proton Wira. The Proton Wira also was known as the Proton Persona (C90) is a car manufactured by Malaysian carmaker Proton from 1993 to 2009. It was produced in four-door saloon and five-door hatchback models and is based on the Mitsubishi Lancer platform. Proton made minor changes to the taillights, bumpers, and dashboard. Five trim levels were available. The 1.6, 1.8 and 2.0-liter models (4G92 and 4G93) were equipped with rear disc brakes, front and rear armrests, electric mirrors, folding rear seats and electric windows on all doors. Proton redesigned the saloon to make a five-door hatchback variant during the mid-1990s, basing the car on the saloon Wira and sporting similar tail lights. The entry level 1.3 and 1.5-liter models lack some of the features of the 1.6 and 1.8-liter models to cut down costs and thus lower the list price. They used 4G13 and 4G15 engines. Parameters used in this research are shown in Table 1, while three types of road profile are shown in Figures 1-3.

TABLE II. PARAMETER USED

Parameter	Type
Road profile	Tar road, Yellow line road, and Dirt road
Car speed	40 km/h, 50 km/h, 60 km/h,70 km/h and 80 km/h
Load quantity	Load A, Load B, Load C (Load A = 1 person, Load B = 2 persons, Load C = 3 persons)

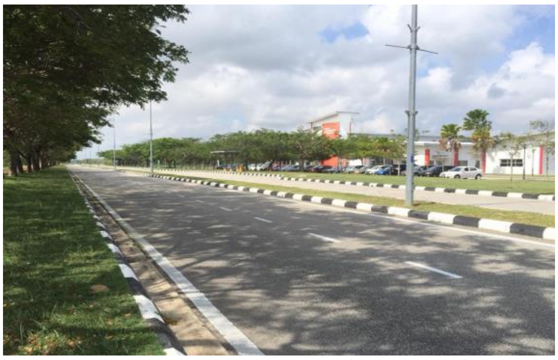

Fig. 1. Tar road profile.

Fig. 2. Yellow line road profile.

Fig. 3. Dirt road profile.

Input data was obtained from two accelerometers attached on the car seat and the frame of the car as shown in Figure 4. 2. The accelerometers are connected to the NI-DAQ. 1. Design a module that includes all the parameters required to obtain data from the car seat vibration with the use of DasyLab software is shown in Figure 5. The car tested on three different road profiles, five types of car speeds and three types of load quantity.

Fig. 4. Accelerometer attached on the car seat.

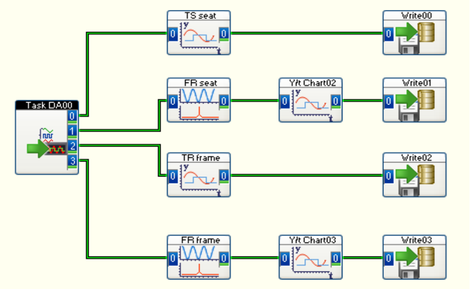

Fig. 5. DasyLab Module.

RESULT AND DISCUSSION

Tables 3-4 are shows result for frequency response at the frame and a seat on normal tar road with five different speeds, respectively. When the car speed and load increase, the results also increase. Results take at frame and seat because these two places are easy to absorb vibration and near load. Table 3 shows that the highest value is at 80 km/h for every load and the highest value for the frequency is 58 Hz. Based on the tables, it has been shown that frequency response at the seat is higher compared to the frequency at the frame. The highest value for frequency response at the seat is 75 Hz. Table 4 shows that when speed increases the frequency also increase. The overall data frequency responses at the frame and seat are shown in Figures 6-7, respectively.

The transmissibility is a ratio between vibration at seat and vibration at the frame. Transmissibility results for each speed and each load on the tar road, yellow line road and dirt road is calculated. The comparison for every load shows in Figure 8. Transmissibility at speed 80 km/h for load 3 achieved the highest value 1.54. Lowest value can be found at load two at speed 30 km/h that is 1.06. From Figure 8, it can be seen that the highest value for transmissibility on yellow line road is 1.73. This can be found at load speed 80 km/h whereas the lowest value is 1.12 at speed 30 km/h under load A. From the graph, load 3 maintains the highest value until speed 60 km/h, and it drops at speed 70 km/h then increase again. Transmissibility at a speed of 80 km/h for load C achieved the highest value 2.05. Lowest value can be found at load one at speed 30 km/h that is 1.27. From the graph, load C maintains the highest value until speed 70 km/h, and it drops at speed 80 km/h, transmissibility values from 2.05 to 2.00. From Figure 4.15, it shows that load 3 have high value for each speed compare to load A and load B. Transmissibility value for each road profile not show big differences. Transmissibility is a ratio; this means when the value is small then vibration at seat and frame not have a lot of differences — results for transmissibility used to compare the vibration at seat and frame. From the results, transmissibility for both road profile does not produce big differences means vibration value produce a seat and frame quite same.

TABLE III. FREQUENCY RESPONSE AT THE FRAME ON THE TAR ROAD

Speed (km/h)	Frequency (Hz)		
	Load A	Load B	Load C
40	19	23	32
50	23	29	39
60	28	35	44
70	33	41	52
80	37	46	58

TABLE IV. FREQUENCY RESPONSE AT SEAT ON THE TAR ROAD

Speed (km/h)	Frequency (Hz)		
	Load A	Load B	Load C
40	26	39	51
50	37	47	58
60	45	61	65
70	50	64	72
80	58	69	75

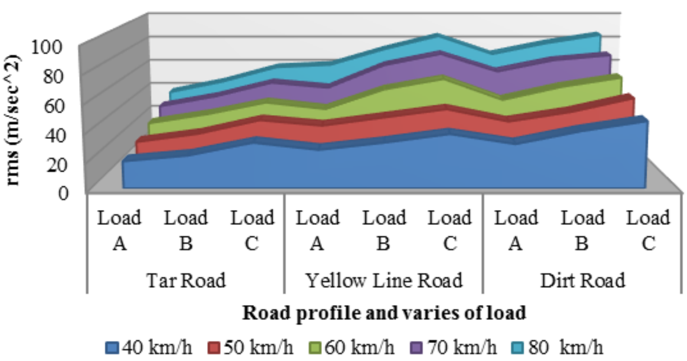

Fig. 6. Frequency Response on the Seat Frame.

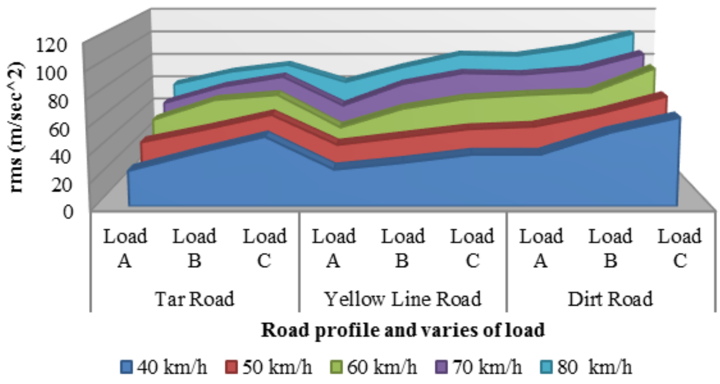

Fig. 7. Frequency Response on the Seat.

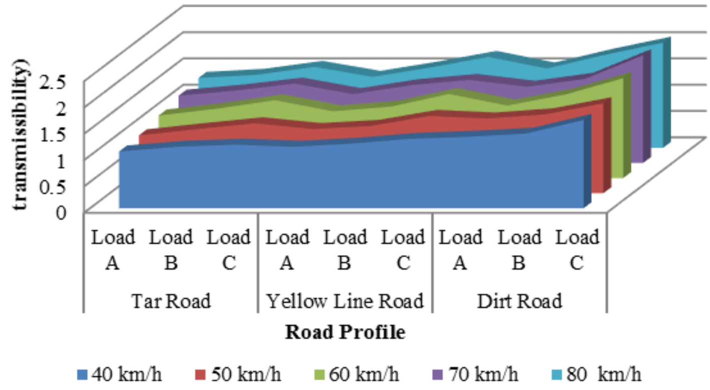

Fig. 8. The transmissibility.

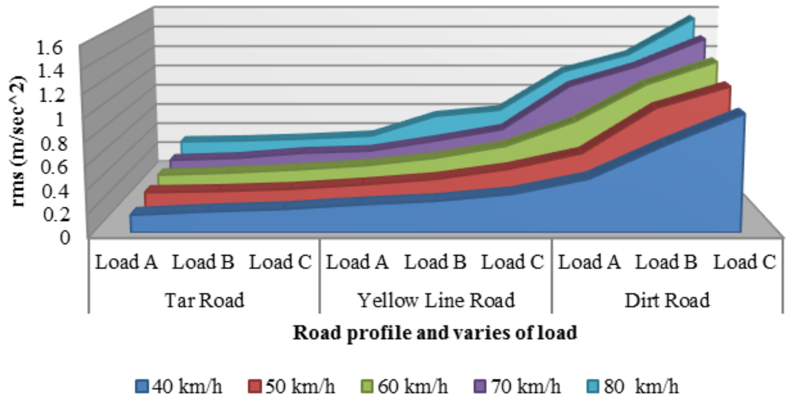

Fig. 9. Ride Comfort Index.

Ride comfort index in Table 5. From this table, it showed that when RMS acceleration is less than 0.315 m/s2, the comfort index will be not uncomfortable. This means it comforts. For value between 0.315 m/s2 and 0.63 m/s2, the comfort index is a little uncomfortable. Ride comfort index will be fairly uncomfortable when RMS acceleration between 0.5 m/s2 and 1 m/s2. If RMS acceleration value 0.8 m/s2 until 1.6 m/s2, comfort index is uncomfortable. For RMS acceleration 1.25 m/s2 to 2.5 m/s2, comfort index is very uncomfortable. When the value of RMS acceleration is greater than 2, the comfort index will become extremely uncomfortable. Based on Table 5, shows comfort index for all load for all road profiles. Comfort index for all speed is not uncomfortable for the tar road profile. Comfort index for all speed is not uncomfortable and a little uncomfortable for yellow line road profile. Comfort index for all speed is not uncomfortable, a little uncomfortable and fairly uncomfortable for yellow line road profile. Comfort index for all speed is a little uncomfortable and fairly uncomfortable for dirt road profile.

TABLE V. RIDE COMFORT INDEX

Speed (km/h)	Tar Road			Yellow Line Road			Dirt Road		
	Load A	Load B	Load C	Load A	Load B	Load C	Load A	Load B	Load C
30	0.13	0.15	0.13	0.22	0.25	0.21	0.30	0.67	0.85
40	0.15	0.18	0.20	0.24	0.27	0.33	0.46	0.75	1.01
50	0.20	0.21	0.23	0.27	0.32	0.41	0.55	0.95	1.14
60	0.22	0.24	0.27	0.31	0.38	0.49	0.72	1.06	1.27
70	0.23	0.25	0.30	0.32	0.42	0.53	0.95	1.14	1.40
80	0.29	0.30	0.32	0.35	0.55	0.61	1.00	1.17	1.53

CONCLUSION

Based on the results achieved, all the parameters such as different road profile, load and speed produced the differences results. Changing the parameter will change the results. This means results are not constant when parameters are changing — results for acceleration response related to transmissibility and RMS acceleration. Based on ISO 2631, the comfort index can be determined. The suitable comfort zone for passengers can also be determined. From the results that already got from the experiment, dynamic comfort, transmissibility and ride comfort index can be analyzed. For transmissibility analysis, the results show that the vibration transfer rate from frame to the seat is not too large. Transmissibility results for each speed and each load on the tar road, yellow line road and dirt road is calculated. Transmissibility at speed 80 km/h for load 3 achieved the highest value 1.54. Lowest value can be found at load two at speed 30 km/h that is 1.06. Comfort index for all speed is not uncomfortable for the tar road profile. Comfort index for all speed is not uncomfortable and a little uncomfortable for yellow line road profile. Comfort index for all speed is not uncomfortable, a little uncomfortable and fairly uncomfortable for yellow line road profile. Comfort index for all speed is a little uncomfortable and fairly uncomfortable for dirt road profile.

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