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Low Frequency Vibration Analysis on Passenger Car Seats

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Abstract_Seating dynamics, and specifically the human perception of the dynamic comfort of a seat, is an area that is of increasing importance to automotive manufacturers catering for a market becoming more and more competitive and sophisticated. A major portion 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. In this project we have evaluated the change in transmissibility under two different terrains, which plays a key role in determining the dynamic comfort. The response of the seat, under smooth and coarse road were found and analysed for four different cars. Long term exposure to high frequency vibration will cause serious health problems in humans. And hence the transmissibility and resonance frequencies were found in the experiment. From the acceleration data, the ride comfort index was found and analysed. The project also aimed at identifying the biological impacts on the passenger due to the vibrations at various frequencies. Thus the project will help us to understand the dynamic comfort, ride comfort index, and the transmissibility at different terrain roads of the car seats under study.

Index Terms_Ride Comfort, Passenger Seat, Vibration Isolation, Transmissibility, Comfort Index, Transmissibility, Ride Comfort Index

1. INTRODUCTION

Seating dynamics, specifically the human perception of the dynamic comfort of a seat, is an area that is of increasing importance to automotive manufacturers catering for a market becoming more and more competitive and sophisticated. A major portion 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.

In India cars are one among the major automobiles used by people for transportation. Apart from pollution and performance, economy, safety and comfort are major factors to consider. Comfort of the driver plays a vital role in the passenger safety, fatigue during long drive, and drivability in heavy traffic. Comfort means absence of any discomfort[1]. A car driver often drives the vehicle through all types of road conditions. While considering the comfort, the seat is one of the main components, which has direct contact to the driver. Seat provides support to the driver, such that the pressure distribution of the seat should be uniform everywhere on the seat. Seat must avoid the vibration transmitted from the road surfaces and power train, in order to avoid back disorder, hand eye coordination, vision impairment etc. Also the prolonged exposure to vibration causes fatigue to the passenger. So to avoid this vibration we require a vibration isolator - seat. Seat should durably serve its intended purpose for its lifetime. To quantify the vibration isolation efficiency of the seat the term Seat Transmissibility is used[2]. It is the ratio of vibration at the top of the seat to the vibration at the frame.

$$\text{Transmissibility} = \frac{vibration\ at\ the\ seat}{vibration\ at\ the\ frame} \quad (1)$$

The transmissibility of the seat will tell us the behavior of the seat at different road condition with different frequency inputs. Transmissibility varies as frequency changes.

The work is an attempt towards studying dynamic characteristics of passenger seat for comfort through objective evaluation[3]. For objective evaluation, the transmissibility and ride comfort Index were found under two different conditions on four different cars. For better understanding the vibration transmissibility key points taken for analysis are:
1. Transmissibility values at different conditions
2. Comfort index as per ISO 2631 for different conditions

2. SEAT EFFECTIVE AMPLITUDE TEST

SEAT % experimental analysis is carried out on driver seat to evaluate gains, seat effective amplitude transmissibility, and is an attempt to understand seating systems damping characteristics under real time conditions. A mass load of 60 kg is used during the test. The vehicle was tested in two road terrains, rough and smooth. The instrumentation and setup used for the experiment is as follows:

1. Vehicle under study
2. Accelerometers 2 Nos
    - Position 1 - Seat base
    - Position 2 - Seat mount
3. Data Acquisition Unit
4. Post processor
5. Rigid dummy (60 kg – equivalent to seating weight)

Input data was obtained from the accelerometer installed at the seat mounts, whereas output data would be obtained from the seat pad accelerometer put on the seat base. The acceleration results are listed as per different experimental conditions. The test was carried out on seat with dummy loaded on it. Output graphs in terms of accelerations vs time (time domain output), accelerations vs frequency (frequency domain output), and transmissibility vs frequency are plotted.

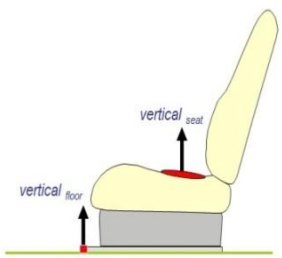

Fig1. Accelerometer position

3. SEAT EFFECTIVE AMPLITUDE TEST OUTPUT

Seat values were obtained for the four car seats by importing the post-processed (power spectrum) data from the analyzer. The “ride on the seat” (output) is the integral of frequency experienced on the seat, whereas the “ride on the floor” (input) is the integral of frequency experienced on the floor. From the basic knowledge of integral, this equation can be stated as the ratio of the area under the graph of “ride on the seat” to the area under the graph of “ride on the floor”, as below [4]:

$$\text{SEAT \%} = \left| \frac{\int Gss(f) * Wi(f) * df}{\int Gff(f) * Wi(f) * df} \right|^{\frac{1}{2}} \text{x } 100 \qquad (2)$$

where, Gss (f) and Gff (f) are the seat and floor power spectral density and Wi(f) is the frequency weighting for the human response to vibration.

3.1 Frequency Weighting for Driver Seat:

With ref. to ISO 2631[5] (Table 1), frequency weighting Wi(f) for Car ‘A’ and Car ‘B’ seat in “Z” axis is considered as “Wk” =1.

Table 1

Weighting factor from ISO 2631

Contact point	Axis	Weighting Curve	Multiplying factor, k
Seat Cushion	x	Wd	1
	y	Wd	1
	z	Wk or Wb	1
Seat back support	x	Wc	.8
	y	Wd	.5
	z	Wd	.4

3.2 Evaluation of Dominant Frequencies and Transmissibility (Gains) Analysis

As per the setup explained above, the vehicle was taken through the test terrain with 60 kg load. Acceleration data from the two accelerometers placed at the seat mount and seat base respectively are taken. The frequency weighted acceleration data is found and from the frequency weighted acceleration data the dominant frequency and transmissibility gains are calculated.

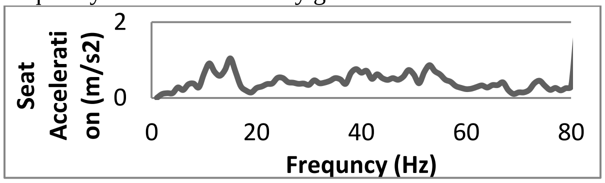

Fig2. Frequency domain data for car A in rough road

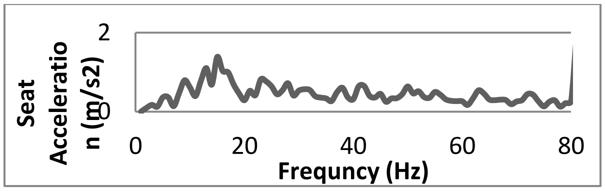

Fig3. Frequency domain data for car A in smooth road

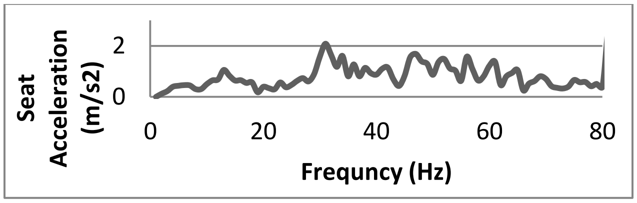

Fig4. Frequency domain data for car B in rough road

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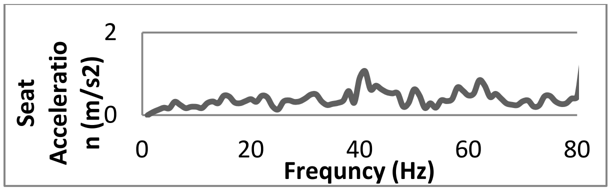

Fig5. Frequency domain data for car B in smooth road

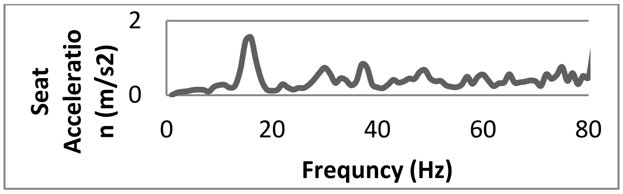

Fig6. Frequency domain data for car C in rough road

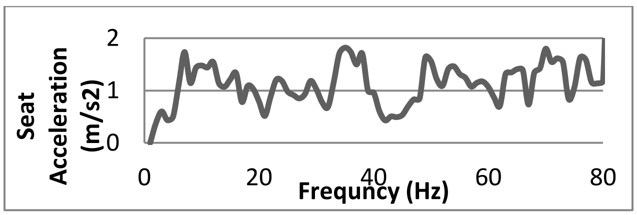

Fig7. Frequency domain data for car C in smooth road

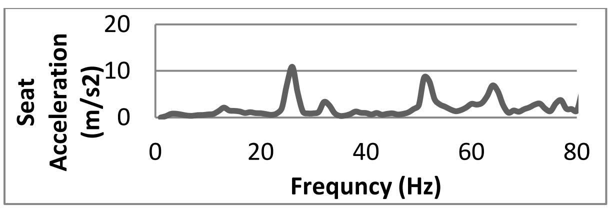

Fig8. Frequency domain data for car D in rough road

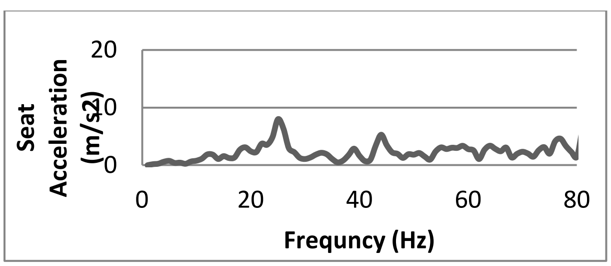

Fig9. Frequency domain data for car D in smooth road

Figure 2 to Figure 9 plots the acceleration on the seat surface in rough and smooth road when loaded with 60 kilogram load. The variation in the vibration levels can be identified from the graph plots. The acceleration data shows that the system has varying performance for each car. The transmissibility ratio has been found for the rough and smooth terrain for 60 kilogram load in each of the four cars. And the transmissibility is plotted with respect to the frequency. 0 - 80 Hertz was considered for the transmissibility analysis, as per ISO 2631.

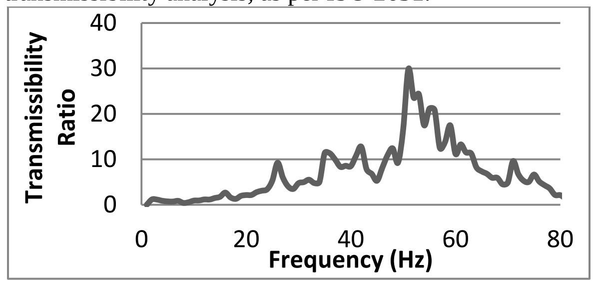

Fig10. Transmissibility data for car A in rough road

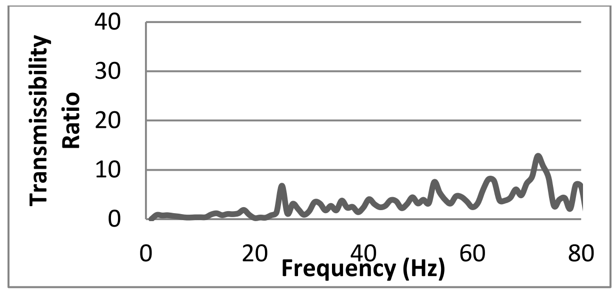

Fig11. Transmissibility data for car A in smooth road

Analyzing the transmissibility ratio for car A in rough and smooth terrain under 60 kilogram load, we can identify that the transmissibility is less in smooth road when compared to rough road. Also the transmissibility in the low frequency region of 0 – 20 Hertz in very low when compared with high frequency range.

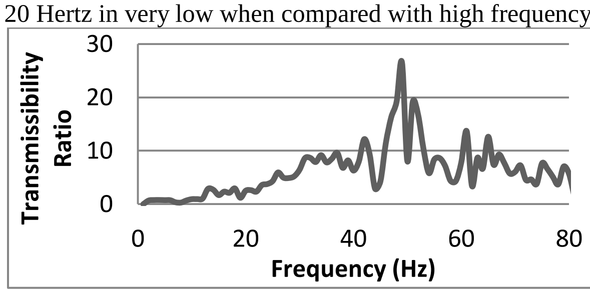

Fig12. Transmissibility data for car B in rough road

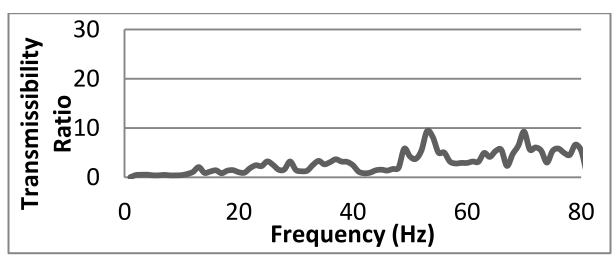

Fig13. Transmissibility data for car B in smooth road

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As of in car A the transmissibility is low for smooth road when compared with rough road terrain. therefore the amplitude of vibration transmitted from the seat base to the seat surface will be low in smooth terrain. But, when the transmissibility ratio is greater than one, the vibration amplitude at the seat surface will be greater than the vibration amplitude at the base.

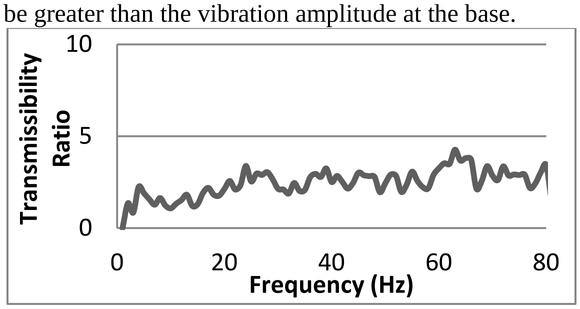

Fig14. Transmissibility data for car C in rough road

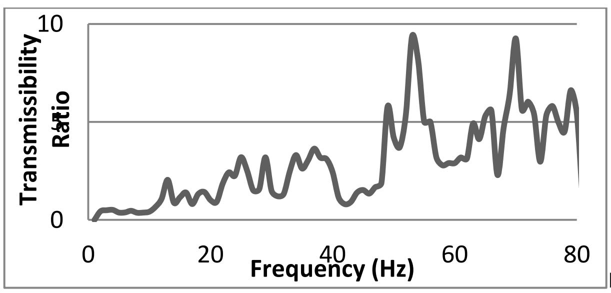

Fig15. Transmissibility data for car C in smooth road

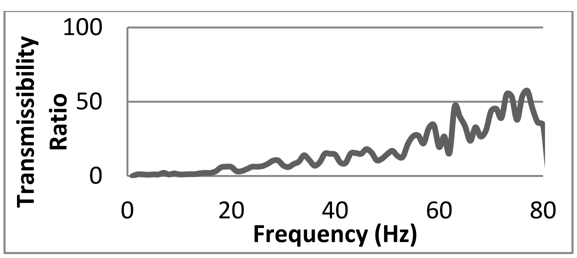

Fig16. Transmissibility data for car D in rough road

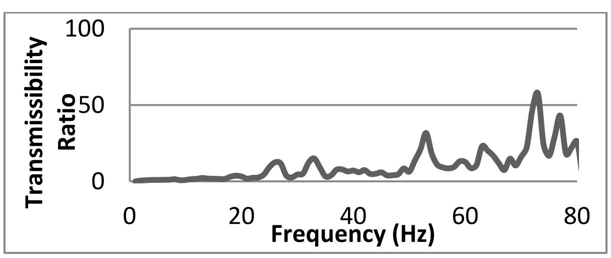

Figure 17 Transmissibility data for car D in smooth road

Comparing the transmissibility of the four cars, the deviation in the transmissibility values with the change in terrain can be found. An increase in the transmissibility is found in the higher frequency range.

4. RIDE COMFORT INDEX

The ride comfort Index value for each car when tested under each terrain is found for 60 kilogram load. The Ride Comfort Index value can identify the comfort zone in which the passenger travels, based on the acceleration values.

Table 2

Ride Comfort Index as per ISO 2631

RMS Acceleration (m/s2)	**Comfort Index**
Less than .315	Not Uncomfortable (C)
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)

From Table 2 the Ride Comfort Index values are found and are given in Table 3. Car B is found to the most comfortable on, when compared with the three other cars. Car B is fairly uncomfortable in rough road condition and is comfortable in smooth road condition. Car A is little uncomfortable in both conditions and where as car C is extremely uncomfortable in rough road and uncomfortable in smooth road. Finally car D is uncomfortable in both terrains.

Table 3

Results for Ride Comfort Index for car A and B

Terrain	Weight	Car A RMS Acceleration (m/s2)	CI	Car B RMS Acceleration (m/s2)	CI
Rough road	60 kg	0.32661	LU	0.51439	FU
Smooth road	60 kg	0.41810	LU	0.25671	C

Table 4

Results for Ride Comfort Index for car C and D

Terrain	Weight	Car C RMS Acceleration (m/s2)	CI	Car D RMS Acceleration (m/s2)	CI
Rough road	60 kg	3.57819	EU	1.2047	U
Smooth road	60 kg	0.95498	U	1.2658	U

5. CONCLUDING REMARKS

The work "Low Frequency Vibration Analysis on Passenger Car Seat" was done successfully to find the dynamic comfort of the passenger car seat under varying road terrains. A test setup for measuring the vibration transmissibility of the passenger car seat in real time condition has been developed. Using the test methodology, transmissibility of the seat under specified test conditions were identified and the relation of transmissibility with road terrain is found. From the experiment conducted under rough and smooth road terrain, it is found that the transmissibility will vary with respect to terrain. ISO 2631 effectively characterises the different vehicles for their ride comfort. Ride comfort index calculated from the acceleration value has identified the comfort of each car in the rough and smooth terrain. Car B was found to be the most comfortable car, even though the index of car B was not comfortable in all test condition.

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