Experimental Analysis of Seat Transmissibility with Cushion Materials for Seat with Cushion and Base Suspension by Multibody Dynamic Approach

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Abstract - *There are many factors that affect to discomfort in a driving vehicle. The human feelings like discomfort and the level of injury can be estimated with this relationship and measured 12-axis whole-body vibration. This discomfort estimation can be used in experimental method in vibrating environment such as vehicle. Transmissibility is non-dimensional ratio of the response amplitude of a system to the excitation amplitude expressed as a function of the vibration frequency. The responses have been widely assessed in terms of the driving-point impedance, apparent mass, and transmissibility. The first two are related to the forces and motion at the driving position such as the position of the hip or floor while the third one is related to the transmission of motion through the human body.*

***Key Words*: Transmissibility, Multi Body Dynamic (MBD), Fast Fourier Transform (FFT), Cushion Materials, Thigh, Hip, Back, Viscera, Head**

1. INTRODUCTION

Ride comfort is influenced by various parameters, such as whole body vibration, road irregularities, tires, suspension system, cab mounts, seat design, sitting posture, noise, etc. The ride comfort depends on the exposure duration, amplitude, and frequency of vibration to a human body. The human body is a dynamic system whose mechanical properties vary from moment to moment and from one organ to the other. Out of all these factors, seat design is important as it is in direct contact with human body. Most vibrations are transferred to the body through the seat contact area. So, it is useful to study the relationship between seat design and the vibrations transferred to the human body.

Research in vibration control has been an on-going study for decades, ever since the invention of mechanical systems. Engineers and researchers have been trying to fully understand the dynamic behaviour of mechanical systems in order to reduce the vibration levels of mechanical systems and simultaneously increasing the human comfort and safety. On top of that, quality of a mechanical systems, which include efficient energy consumption, safety, and revision of comfort to the user are highly desired.

In respect to vehicle comfort, car seat is one of most important part. Since it is direct in contact with human body and transfers vibrations to human body coming from vehicle base. But development of new car seats is very costly and time consuming since it is depend on experimental procedures on prototypes. Hence computer simulation models can save cost and time for development of new car seats. For a multibody dynamics (MBD), many researches have been done. For this purpose, we can use multibody dynamic software MSC ADAMS. We can propose transmissibility results for different cushion materials.

In this work we will propose multibody dynamic simulation of car seat model with human in sitting posture. By measuring vertical vibration transmissibility for different body segments using model and results validated with available experimental model.

2. DEVELOPMENT OF EXPERIMENTAL SETUP

In the study and analysis, most important part for comfort is car seat because it is in direct contact with human body and transfers vibrations coming from base to human body. It is proposed to reduce the seat transmissibility. Optimization of the seat transmissibility can be done by two methods

a) Optimizing the human body and seat parameters.
b) Optimizing the cushion materials.

Out of these two methods, optimization of seat transmissibility by the first method will be already done by various research persons. From this theoretical analysis we got **a seat with both suspension and a cushion** is the best setup for reducing vibrations transmitted to the human body. Now in this paper we will optimize the transmissibility by changing cushion material.

Since human body is in direct contact with car seat, vibrations are transferred from seat to human body. So main objective for this analysis is to reduce vibration transfer ratio. We can optimize the data to get comfortable seats.

For this, we have considered vibration analysis for car seat model-

2.1 Seat with cushion and base suspension.

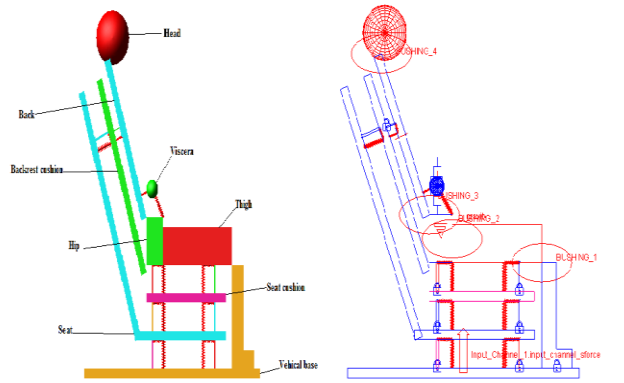

Fig.1 Seat with cushion and base suspension

Fig.1 show car seat model with cushion and base suspension. We referred this from ref [8] and used for vibration analysis. This model is provided with seat cushion and backrest cushion as well as base suspension. So mostly vibrations are coming to human body from vehicle floor are isolated. This model has a total 20 DOF's.

With motivation from previous analysis [1],[2] & [3] the experimental setup is developed to analyze the behavior of human body against vibrations which is transferred to it from the road. FFT analyzer is used to measure the vibration transferred to human body.

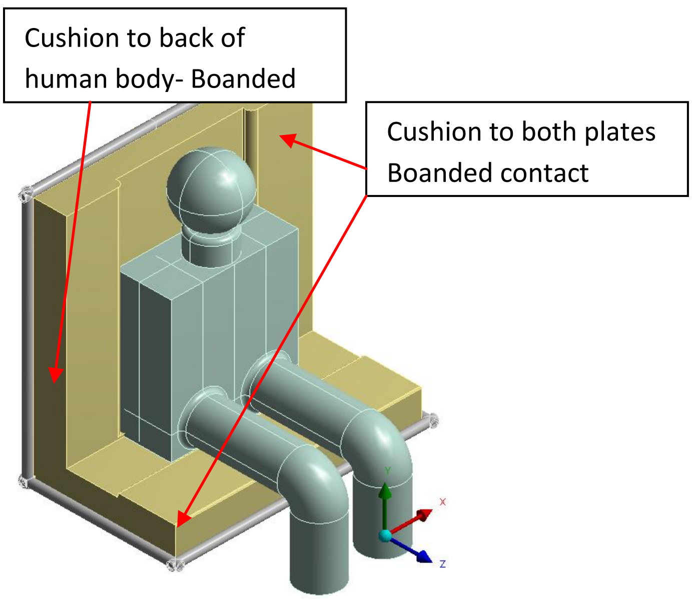

Fig.2 Car seat model with cushion and base suspension

The car seat model as shown in Fig.2 consist of a seat with cushion and base suspension model prepared in Catia. For this model we have considered here is a bonded contact between seat, cushion and other parts of human body.

2.2 Loading and boundary conditions

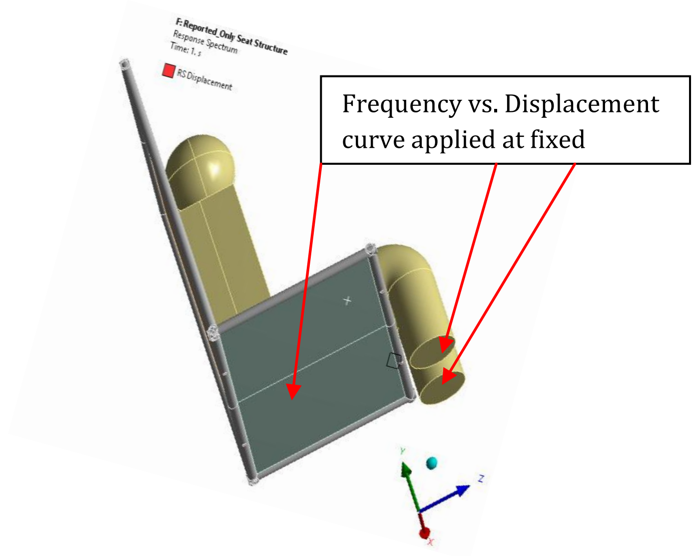

Fig.3 Loading and boundary conditions

2.3 Only seat structure

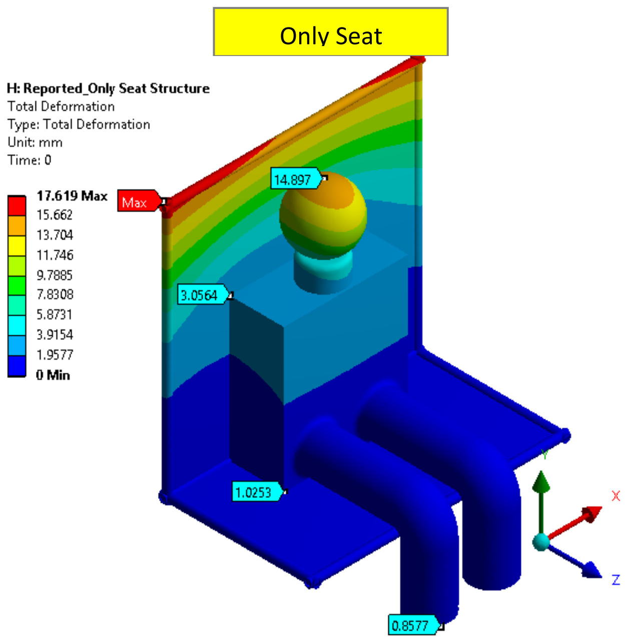

Fig.4 Only seat structure

2.4 Seat with cushion material -2M

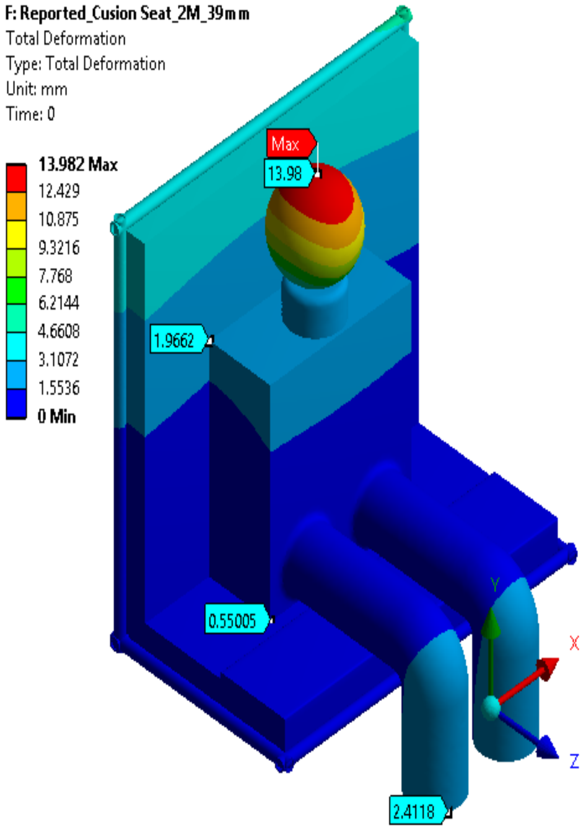

Fig.5 Seat with cushion material – 2M

2.5 Seat with cushion material -2H

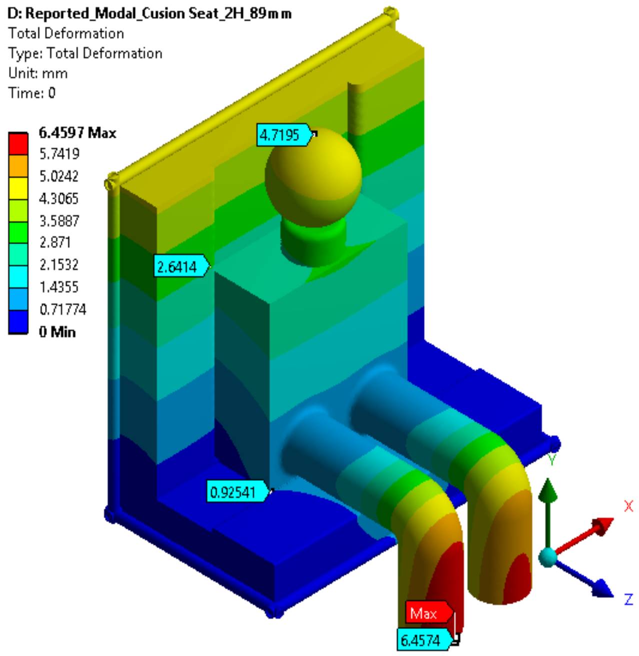

Fig.6 Seat with cushion material – 2H

2.6 Seat with cushion material -4.4 M

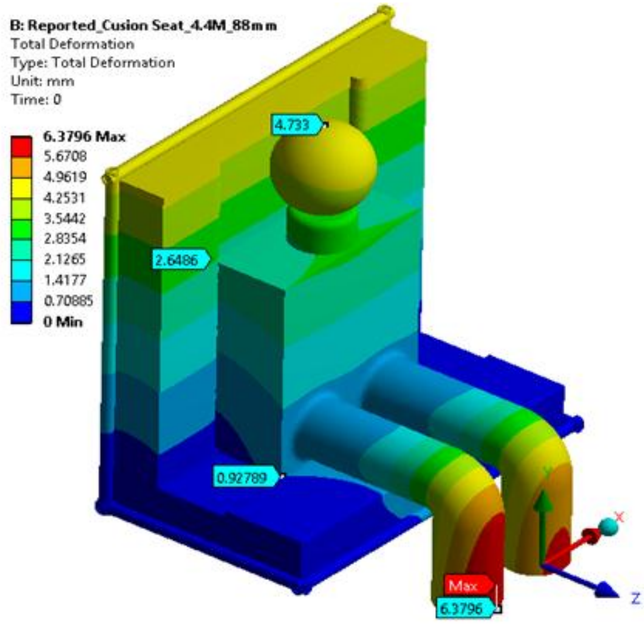

Fig.7 Seat with cushion material 4.4 M

3. EXPERIMENTATION

1. Start the electric motor which is having unbalanced mass attached to shaft. This unbalanced shaft is used to create vibrations.
2. Selected the proper sensor and their channel is made in vibration analyser. Defined the measurement parameters. i.e. measurement of velocity of vibrations transferred to different body parts with channel I to which accelerometer is connected.
3. Attached all sensors to vibration analyser when it is in off condition. Connections of all sensors should be in correct position.
4. Kept first cushion material on seat. Then human body is kept on seat.
5. Accelerometer is attached to thigh i.e. first body part to measure velocity transferred from seat to body.
6. Similarly experimentation is carried out for remaining body parts. i.e. hip, back, head and viscera.
7. After first set of reading for cushion material, changed the cushion material and same procedure is carried out.
8. In this way we checked three cushion materials and obtained different graphs of velocity vs. frequency.
9. After getting graphs electric motor is stopped.

4. INSTRUMENTS USED FOR EXPERIMENTATION

4.1 The Sensing Equipment

An accelerometer is a sensing element that measures acceleration; acceleration is the rate of change of velocity with respect to time. It is a vector that has magnitude and direction. Accelerometers measure in units of *g*, where *g* is the acceleration measurement for gravity which is equal to 9.81 m/s^2. Accelerometers have developed from a simple water tube with an air bubble that shows the direction of the acceleration to an integrated circuit that can be placed on a circuit board. Accelerometers can measure: vibrations, shocks, tilt, impacts and motion of an object. Accelerometer used is as shown in Fig 8

Fig. 8 Accelerometer

4.2 Data Acquisition and Processing Equipment

A Fast Fourier Transform (FFT) is an algorithm to compute the Discrete Fourier Transform (DFT) and its inverse. A Fourier transform converts time (or space) to frequency and vice versa; an FFT rapidly computes such transformations by factorizing the DFT matrix into a product of sparse (mostly zero) factors. As a result, Fast Fourier Transforms are widely used for many applications in engineering, science, and mathematics. The basic ideas were popularized in 1965, but some FFTs had been previously known as early as 1805. Fast Fourier Transforms have been described as "the most important numerical algorithm of our lifetime".

Before the mathematical FFT process can be applied, a certain amount of data representing the waveform has to be stored in memory as a so-called "time record". The minimum duration of this time record is the period of the lowest frequency to be processed. The time this takes is called collection time. Then the whole waveform is analyzed in one go and mathematically converted into a series of sine waves of different amplitudes, frequencies and phases. The result is an analysis of the whole spectrum part at a certain point in time. The FFT procedure implies that the collected signal is continuously present for an infinite time. This means that the result is based on the assumption that the collected waveform in the time record repeats itself over and over. If the amplitude of the original signal is not zero at the beginning and the end of the time record, the FFT will compute a result for a waveform having sharp edges at every collection interval.

The A4400 - VA4 Pro has modules for analyzing, data collecting and the recording of vibration signals. The instrument is enhanced by modules for dynamic balancing, measurement of run up and cost down, control and checking of lubrication and listening to vibration signals by the stethoscope feature. The instrument is equipped with an expert system developed by Adash, which automatically detects machinery defects.

Four Channel FFT Analyzer used is as shown in Fig.9.

Fig.9 FFT Analyser

5. GLIMPSES OF EXPERIMENTATION

Fig. 10 Testing of experimental setup

6. EXPERIMENTAL RESULTS

A) Case I: Cushion Material (2M).-

A.1. Vibration results with cushion material (2M) characteristics for thigh.

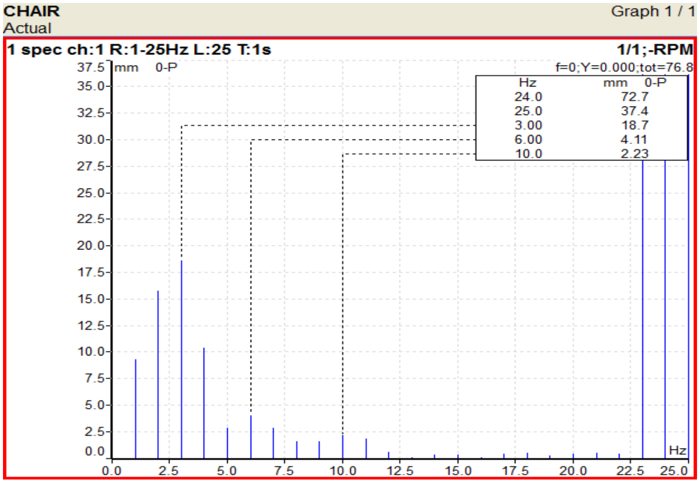

Fig.A1: Transmissibility results for Thigh (2M)

Magnitude	Frequency
18.7	3.0

Table A1: Transmissibility results for Thigh (2M)

A.2. Vibration results with cushion material (2M) characteristics for Hip.

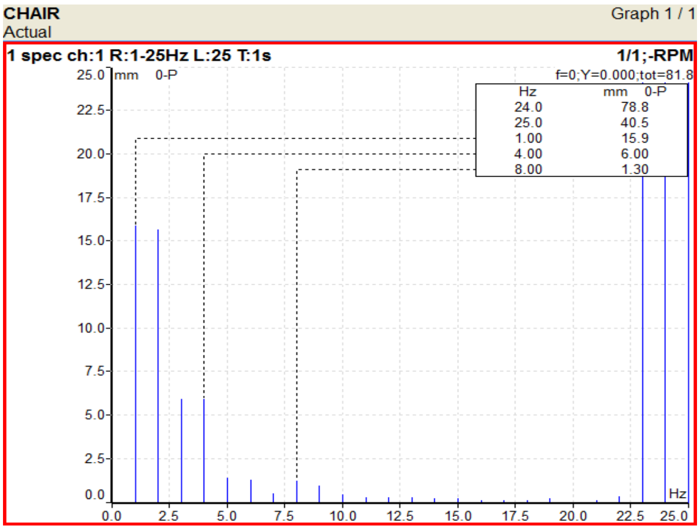

Fig.A2: Transmissibility results for Hip (2M)

Magnitude	Frequency
15.9	1.0

Table A2: Transmissibility results for Hip (2M)

A.3. Vibration results with cushion material (2M) characteristics for Back.

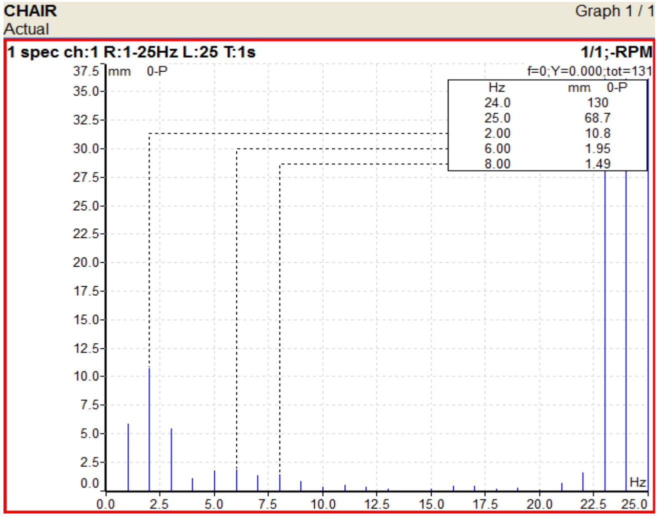

Fig.A3: Transmissibility results for Back (2M)

Magnitude	Frequency
10.8	2.0

Table A3: Transmissibility results for Back (2M)

A.4. Vibration results with cushion material (2M) characteristics for Head.

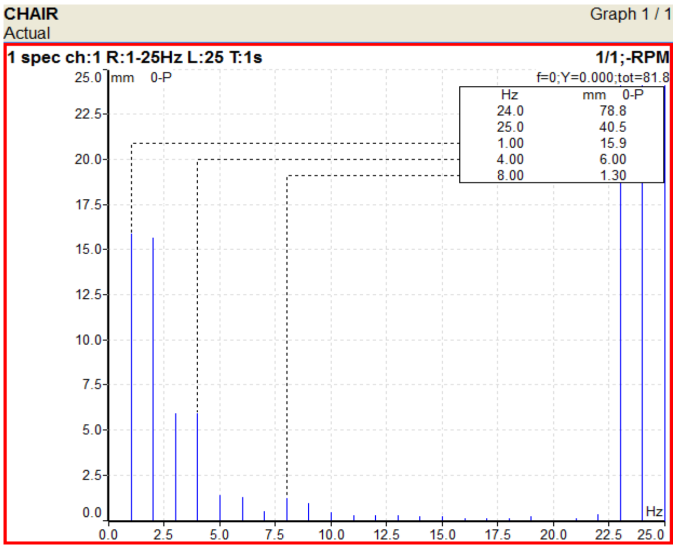

Fig. A4: Transmissibility results for Head (2M)

Magnitude	Frequency
15.9	1.0

Table A4: Transmissibility results for Head (2M)

A.5. Vibration results with cushion material (2M) characteristics for Viscera.

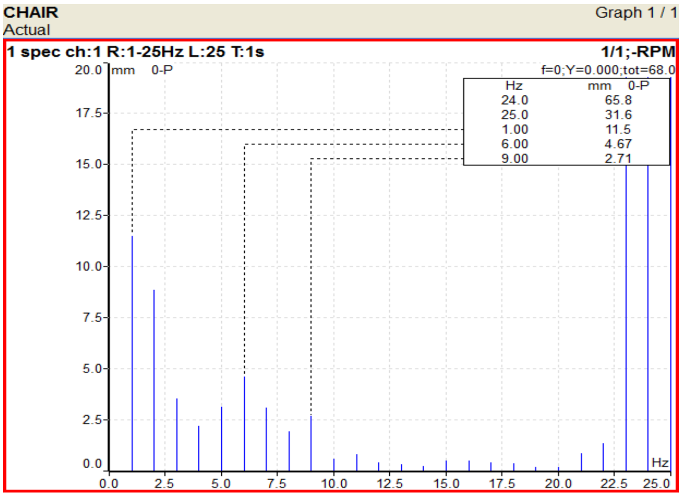

Fig. A5: Transmissibility results for Viscera (2M)

Magnitude	Frequency
11.5	1.0

Table A5: Transmissibility results for Viscera (2M)

B) Case II: Cushion Material (2H)

B.1. Vibration results with cushion material (2H) characteristics for Thigh.

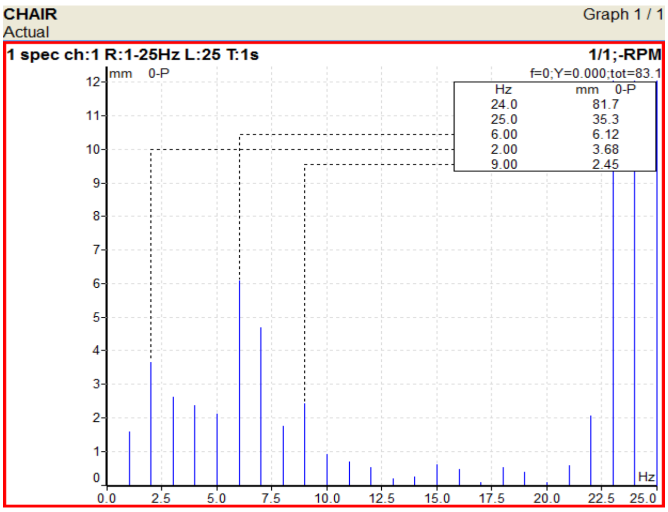

Fig.B1: Transmissibility results for Thigh (2H)

Magnitude	Frequency
6.12	6.0

Table B1: Transmissibility results for Thigh (2H)

B.2. Vibration results with cushion material (2H) characteristics for Hip.

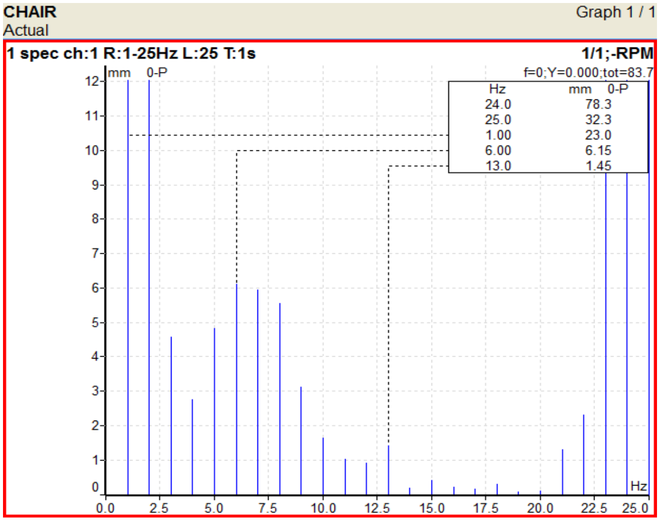

Fig.B2: Transmissibility results for Hip (2H)

Magnitude	Frequency
6.15	6.0

Table B2: Transmissibility results for Hip (2H)

B.3. Vibration results with cushion material (2H) characteristics for Back.

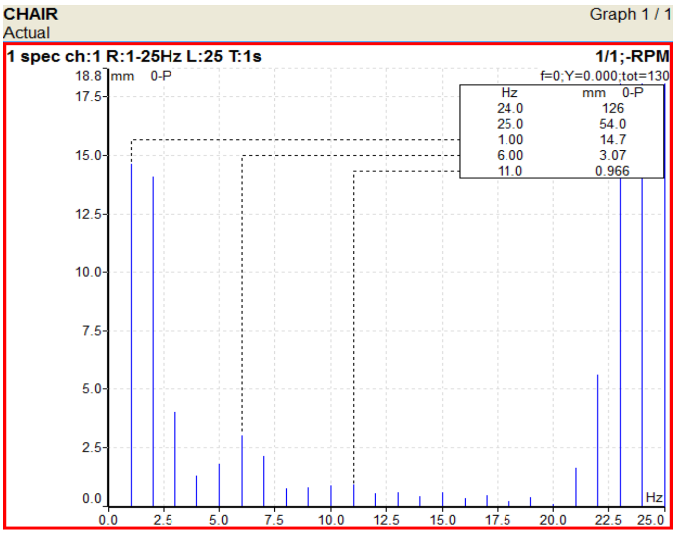

Fig.B3: Transmissibility results for Back (2H)

Magnitude	Frequency
3.07	6.0

Table B3: Transmissibility results for Back (2H)

B.4. Vibration results with cushion material (2H) characteristics for Head.

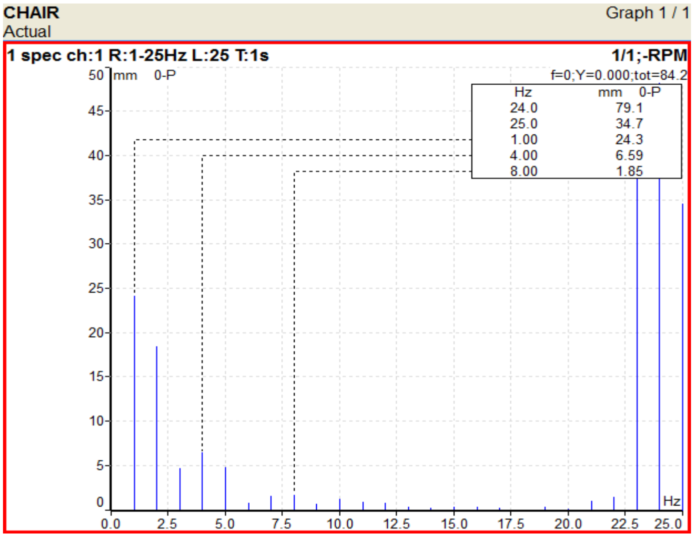

Fig.B4: Transmissibility results for Head (2H)

Magnitude	Frequency
6.59	4.0

Table B4: Transmissibility results for Head (2H)

B.5. Vibration results with cushion material (2H) characteristics for Viscera.

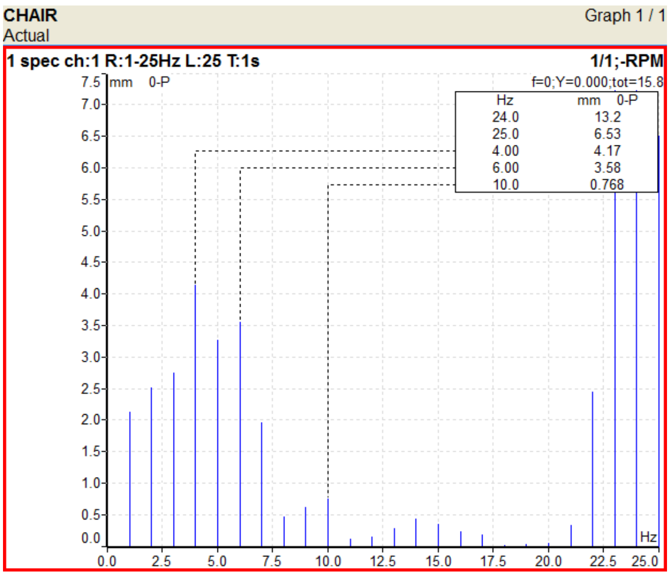

Fig.B5: Transmissibility results for Viscera (2H)

Magnitude	Frequency
3.58	6.0

Table B5: Transmissibility results for Viscera (2H)

C) Case III: Cushion material (D)

C.1. Vibration results with cushion material (D) characteristics for Thigh.

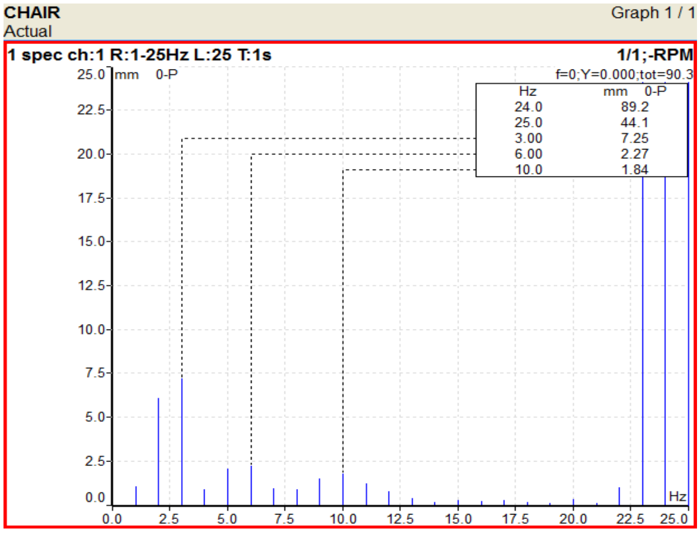

Fig.C1: Transmissibility results for Thigh (D)

Magnitude	Frequency
2.27	6.0

Table C1: Transmissibility results for Thigh (D)

C.2. Vibration results with cushion material (D) characteristics for Hip.

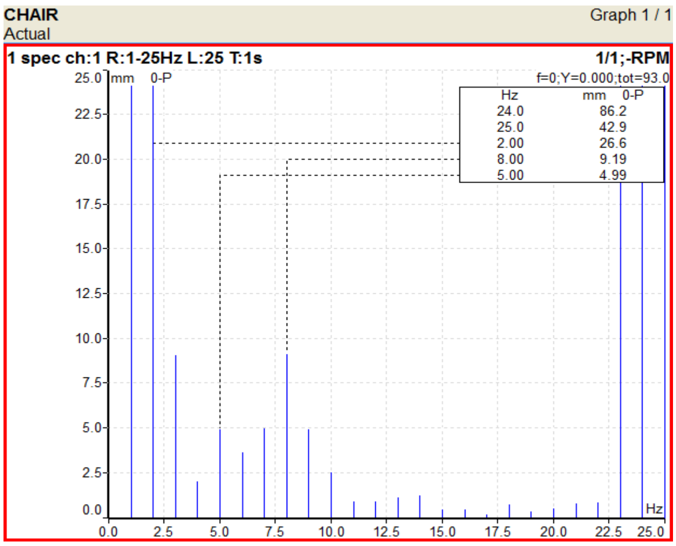

Fig.C2: Transmissibility results for Hip (D)

Magnitude	Frequency
4.99	5.0

Table C2: Transmissibility results for Hip (D)

C.3. Vibration results with cushion material (D) characteristics for Back.

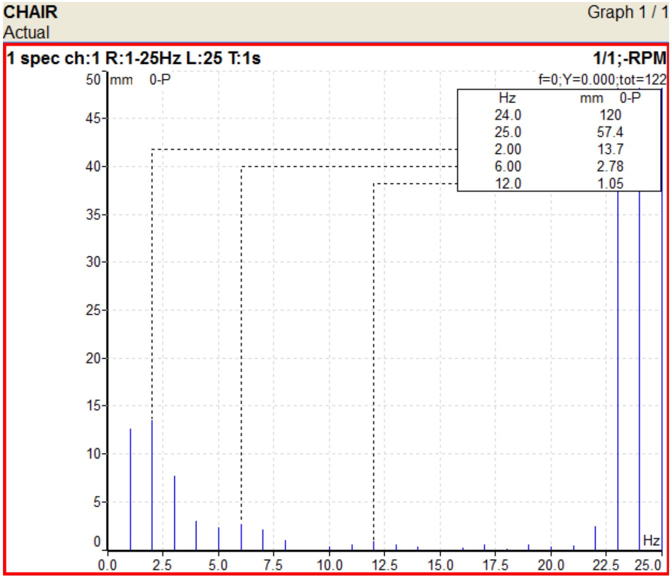

Fig.C3: Transmissibility results for Back (D)

Magnitude	Frequency
2.78	6.0

Table C3: Transmissibility results for Back (D)

C.4. Vibration results with cushion material (D) characteristics for Head.

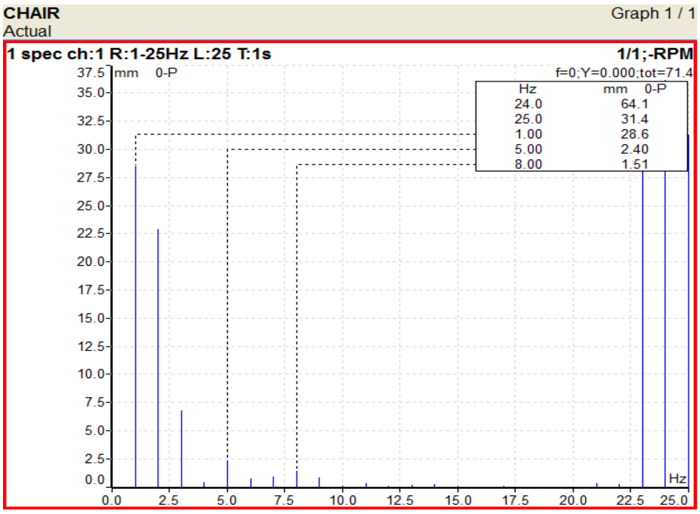

Fig.C4: Transmissibility results for Head (D)

Magnitude	Frequency
2.40	5.0

Table C4: Transmissibility results for Head (D)

C.5. Vibration results with cushion material (D) characteristics for Viscera.

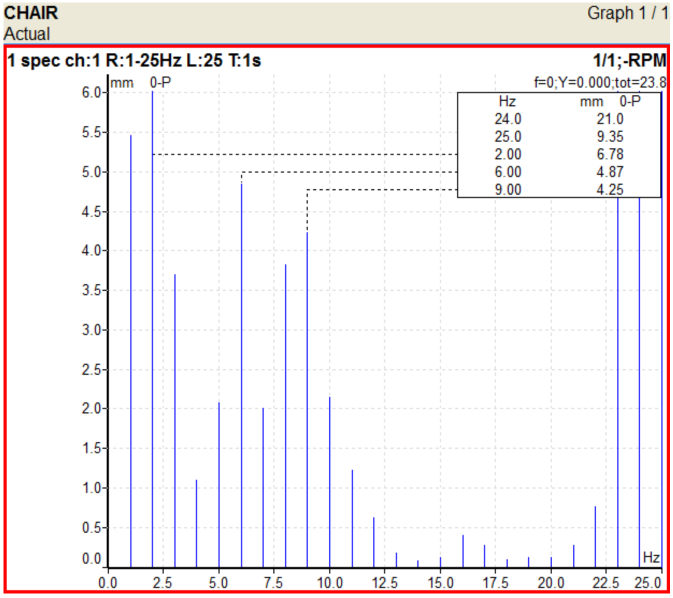

Fig..C5: Transmissibility results for Viscera (D)

Magnitude	Frequency
4.87	6.0

Table C5: Transmissibility results for Viscera (D)

7. RESULT SUMMERY

Experimentation Results Summery						
Cushion Material	2M		2H		D	
Parameters	Magnitude	Frequency	Magnitude	Frequency	Magnitude	Frequency
Thigh	18.7	3.0	6.12	6.0	2.27	6.0

Hip	15.9	1.0	6.15	6.0	4.99	5.0
Back	10.8	2.0	3.07	6.0	2.78	6.0
Head	15.9	1.0	6.59	4.0	2.40	5.0
Viscera	11.5	1.0	3.58	6.0	4.87	6.0
Range	**10.8 to 18.7**	**1.0 to 3.0**	**3.07 to 6.59**	**4.0 to 6.0**	**2.27 to 4.99**	**5.0 to 6.0**

Table 1: Transmissibility result for three cushion material

For this analysis we considered frequency range between 1 Hz to 8 Hz and magnitude which shows values near to that of MBD simulation results. Due to this it becomes useful to get proper comparison between software and experimentation results. {Note: These characteristics are changeable from moment to moment and from individual to another because the human body is a complex active dynamic system.}

8. CONCLUSION

In this, the experimental analysis of seat with cushion and base suspension by using different cushion materials is carried out. The vertical displacement of vibrations given to seat by changing different cushion materials (2M, 2H & D) is observed and recorded. From this experimental analysis it is observed that there is considerable difference in vertical displacement of human body by using different cushion materials. Thus by changing various cushion materials we can reduce the vibrations transferred to human body which is seated on it.

This experimental result shows the materials 2M is showing lowest frequencies but more transmissibility. 2H and D are showing almost same frequency and approximately equal transmissibility magnitude. Out of these three cushion materials D has lower transmissibility and 2H has higher transmissibility.

9. FUTURE SCOPE

Seat with cushion and base suspension by varying cushion materials gives satisfactory results with which we can reduce vibrations transferred to human body. Hence by taking encouragement from this future work can be carried out as follows:

- By selecting proper spring stiffness of seat suspension, vibrations transferred to human body can be reduced.
- Also by choosing correct damping values of cushion material, transmissibility can be improved.
- Various optimization techniques can also be applied in order to obtain optimum results.
- By applying combination of cushion materials we can also improve humans ride comfort.
- By changing model parameters like spring stiffness, damping coefficients and seat part masses we can reduce vibration transmissibility and can develop more comfortable car seat.

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