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Formation and Analysis of Vibratory Model for Seated Posture of a Driver

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ABSTRACT

Entire body vibration causes a multi fascinated sharing out of vibration within the body and disagreeable feelings giving rise to discomfort or exasperation result in impaired performance and health means. This distribution of vibration is dependent on intra subject variability's and inters subject variability.
For this study a multi degree of freedom lumped parameter model has taken for analysis. The equation of motion is derived and the response function such as seat to head transmissibility (STHT) driving point mechanical impedance (DPMI) and apparent mass (APMS) are determined.

Key words: Seat to head transmissibility (STHT), apparent mass (APMS), driving point mechanical impedance (DPMI)

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INTRODUCTION

Many researchers give their opinion about the vibrations of human body for both sitting as well as standing posture. Vibration is the main cause called oscillation to move up and down, which affect the human comfort while driving, loss in productivity and various problems depending upon subjects like human age, human posture, magnitude of vibration and the time to exposure of vibration. The driver of vehicle exposed to more vibration mostly originating from interaction between road and vehicles. This vibration may cause human to discomfort or any type of injury, for all of this purpose many researchers discussed about human model. Model is Consist of lumped parameters. The lumped parameters model is used to depict and to evaluate the human dynamic properties under the vibration. The lumped parameter model Consist of interconnection of various ideal masses, dampers, springs, which are prove to be effective involved in human body exposure to whole body exposure .The model have been developed to evaluate the motion (oscillation) from single degree of freedom to Multi-degree of freedom models. The human body model is useful to simulate human response, which consist of various Branches like head, legs, right and left arms, as well as right and left legs model as a lumped masses. The parameter employed in study are driving point mechanical impedance (DPMI), Apparent mass (APMS) and Seat to head transmissibility function (STHT).

These various parameters can evaluate the vibration to body and how much particular Element affected by vibration.

LITRETURE REVIEW

In 2011,wael abbas', and et al[1] ,In journal of mechanics engineering and automation present 4DOF model of human body with linear seat suspension and Coupled with half car model. For this model he applied a genetic algorithm to search for optimal parameters of seat in order to minimize seat suspension deflection and drivers body acceleration to achieve best comfort to drivers. The optimal linear seat model for the 4 DOF model was determined by genetic algorithm, and compared with current passive parameters, concluded that the optimal seat suspension has limitation on improving the vibration isolation, also the results and plots indicates that optimal linear seat suspension system is less oscillatory and have lower values of maximum overshoots than passive suspension System which is directly related to drivers fatigue, discomforts and safety.

In 1971, Hopkins', [2] et al, developed 3 DOF model of human seated model consisting of upper torso, viscera and lower torso connected in series, For construction of model a bilinear spring were used to connect upper torso with viscera and viscera with lower torso, The model performance was compared with experimental impedance and transmission data values .The model displayed the same number of resonance and peaks as experimental impedance data but had different peak values. The model did not match with experimental transmissibility data either in shape or peak values.

In 1974,Muksian and Nash [3],presented 7 DOF non linear model dedicated to analysis of vibration imposed on seated diaphragm abdomen and pelvis. Linear spring were used between head and back and between back and pelvis, forces associated with relative motion of torso with respect to back and muscles forces were included in model as forces acting directly on masses. In that the sources of stiffness model were not provided but values were similar to experimental data obtained by vogt et al [4]. The model performances were compared with experimental data for acceleration ratio given by Goldman and von Girke et al [5]. At higher frequencies, the model performance was significantly different than that observed experimentally. Matsumoto and Griffin [6] compared the dynamic responses of the human body in both standing and sitting positions. The apparent mass and transmissibility to the head, six locations along the spine, and the pelvis were measured with eight male subjects exposed to vertical random whole-body vibration. In both postures, the principal resonance in the transmissibility occurred in the range 5 to 6 Hz, with slightly higher frequencies and lower transmissibility in the standing posture.

In 1960, Coermann [7] presented a 6-degree-of-freedom (DOF) model of a human (for standing and sitting postures) used to simulate human dynamic response to longitudinal vibration of very low frequencies. This model included masses for the head, the upper torso, the arm-shoulder, a simplified thorax-abdomen subsystem, the hips, and the legs. A nonlinear spring was connected between the upper torso and the hips in parallel with the thorax-abdomen subsystem to represent the elasticity of the spinal column. Model parameters for each element were estimated from measurements of the mechanical impedance. The performance of the whole-body model was not published and is therefore difficult to assess. The characteristics of the spine and the thorax-abdomen subsystem, however, were evaluated in detail. Each was modeled with 1 DOF in the whole-body model. Damping was not included in the spine and the performance of the thorax abdomen subsystem did not match the experimental data particularly well.

In 1976, Muksian and Nash [8] presented a 3-DOF model of the human body in the sitting position that contained a parallel connection between the pelvis and the head. It included masses associated with the head (m1), body (m2), and pelvis (m3) connected in series, very similar to the model given by Coermann et al. [7]. It neglected the arms and legs, and combined the mass of the upper torso and thorax-abdomen into that of the body. The model was based on the assumption that: (1) all springs (kp1, kp2, and kp3) were linear in the frequency range between 1 and 30 Hz, (2) the damping between the head and body (cp2) was zero, and (3) all other dampers (cp1and cp3) were linear between 1 and 6 Hz but nonlinear between 6 and 30 Hz. The values of the masses were obtained from Hertzberg and Clauser [9]. The spring stiffness and damping coefficients were determined by matching existing experimental data at corresponding input frequencies by Magid et al. [10] and Goldman and von Gierke [11]. Since two kinds of damper were used for different frequency ranges, the model performed well when compared with experimental data for single-frequency input. However, since the damping values depend on the input frequencies, analysis of the model performance is difficult to assess for conditions involving multiple-frequency input (i.e., random vibration).

In 1987, ISO [12] published a 4-mass, 8-DOF model of a human for both sitting and standing positions. No correlation between the elements of the model and anatomical segments was established. Each spring damper set connecting masses included two springs and one damper (one spring parallel to the damper and the other in series). The model was developed to match a composite average seat-to-head acceleration transmissibility vs. frequency profile (amplitude and phase for the frequency range of 0.5 to 31.5 Hz) derived from existing experimental studies. The model matched the experimental data very well except for the transmissibility amplitude in the high-frequency range.

In 1987, Nigam and Malik [13] developed a 15-DOF un-damped model for which only a standing posture was considered. It included masses for the head, neck, upper, central, and lower torso, upper and lower arms, upper and lower legs, and feet. The mass of each element was obtained from a previous anthropomorphic body segment study by Bartz and Gianotti [14]. The stiffness was obtained by combining the stiffness of adjacent segments. The model performance was compared with some experimental data such as resonance peaks from Goldman and von Gierke [11], and resonant frequencies for two modes from Greene and McMahon [15]. The natural frequencies of the model were in the range of the experimental resonant data but were relatively high. The leg stiffness was compared with the experimental values from Greene and McMahon [15]. The approximate value of the single leg was 15% larger than the experimental data. As damping was ignored in this study, the model is less realistic and general.

In 2012,Zulkifli Mohd Nopiah [16]et al provide a program for optimization of noise and vibration model in passenger car cabin .In this paper effects of vibration to noise in passenger car cabin were investigated .A vehicle acoustical comfort index (VACI) was used to evaluate the noise annoyance level and vibration does value (VDV) was used to evaluate the vibration level. They show that the increases of VACI values correspond to decrease level of vibration, and that of VDV decrease with increase of VACI values. Which conclude that more values of vibration can produce more annoyance of noise, also that increase of engine speed can influence the annoyance level by decreasing values of vehicle acoustical comfort index, in other words it will contribute to more noise. By modifying the particular structure of car system to reduce the exposed vibration level, we are able to increase the VACI values and at same time decrease the level of noise in passenger car cabin.

According to Nicola cofelice et al [17], as published in international journal proposed a 3 dimensional model for virtual human dummy to represent a biomechanical response due to whole body vibration .They developed a model using a multi body simulation (MBS) and simulation environment LMS virtual lab. They take a detailed spine assembly in order to evaluate the human frequency response in the entire range at interest of whole body vibration. The model has been completely parameterized and model can be set up automatically allowing defining percentile of dummy and initial position. The model in car occupant position has been mainly used to compute human vibration models and transmissibility functions.

In 2010,Li-xin Guo and Li-pin Zhang[18] present a mechanical and mathematical model of half car,5 DOF of vehicle was established ,as well as the psudo excitation Model of road condition for the front wheel and rear wheel .By psudo excitation scheme the equation of transient response and power spectrum density were established ,after performing simulation to vehicle vibration of changeable driving show that psudoexcitation method is more convenient than traditional method and the smoothness computation problem of vehicle, while psudoexcitaton method is used to analyze the vehicle vibration under non-stationary random vibration.

In 2011, Dragon sekulic et al[19], presented a paper to determine aspiring stiffness and shock absorber damping values of bus suspension system ,needed to have acceptable oscillatory behavior. He analyses 3 important oscillatory parameters in frequency area. This type of analysis allows to choice values of oscillatory parameters of bus suspension system depending on different excitation frequency values, likewise the analysis facilitate the choice of oscillatory parameters values for excitation frequency range which exerts a considerable influence on oscillatory behavior of bus. Which in turn is of great importance while designing bus suspension system and found that the changes in suspension oscillatory parameters had effect that,
1. The drivers riding comfort was decreased as bus suspension spring stiffness was increased for excitation frequency to resonant frequencies of bus body.
2. Suspension deformation was reduced as bus suspension spring stiffness was increased at excitation frequencies below 1 Hz, within the zone of resonant frequency of sprung mass, the deformation amplitudes were increased as spring stiffness increased.
3. Higher shock absorber damping values provide better oscillatory comfort for the driver at excitation frequencies close to resonant frequency of bus body. At excitation frequencies above 1.5 Hz, the shock absorber with lower damping coefficient values ensured greater oscillatory comfort.

In 2010,Desta M. et al [20] taken an experiment in which he takes Wan's and Schimmel's (1995) 4 DOF lumped parameter model similar to the an automotive seating environment without back rest support .In order to study dynamic response of model the analytical study first implemented for the model to derive the equation of motion. He simulates the dynamic response under random vibration. The random vibration are collected from 6 Indian railway trains at seat position using tri-axial accelerometer is used as an input ,to analyze the dynamic response of the model. Concluded that the response acceleration spectral density with high vibration level is high and implies that the human beings feel more discomfort as vibration level increases, the spectral density of viscera is more related to other position of the body. The output acceleration spectral density of response function show that the peak values occurred between 3.4 to 5 Hz, for seat to head, seat to upper torso, seat to viscera transmissibility's for different vibration level. The peak values decreases as vibration magnitude decreases .The acceleration spectral density of viscera has attained maximum at peak values more than other position, and vibration level has significant effect at resonance frequency and has less effect as frequency increases.

Vikas Kumar et al [21] had studied the bio-dynamic response of human body to whole body vibration to find out the cause of health and comfort deterioration of human body. For that the transmissibility of whole body (WBV) from floor to the head and knee has been studied. For that study he takes six healthy males subject were exposed to random whole body vibration having0.5 $m/s^2$and 1m/s^2rms vibration magnitude and frequency ranges from 1-20 Hz, also the effect of two hand support (handle and handrail) on floor to head transmissibility as well as floor to knee transmissibility, Resulting that large peaks magnitude in transmissibility has been Observed at knee compared to that of head for each direction of vibration and in both posture. The higher transmissibility at knee than head may be due to damping of vibration as it passes through human body. Muscles and tissues of human body have ability to damp the vibrations which are having complex properties. The transmissibility In handrail posture has been greater than the transmissibility in holding the handle posture.

PROPOSED METHODOLOGY

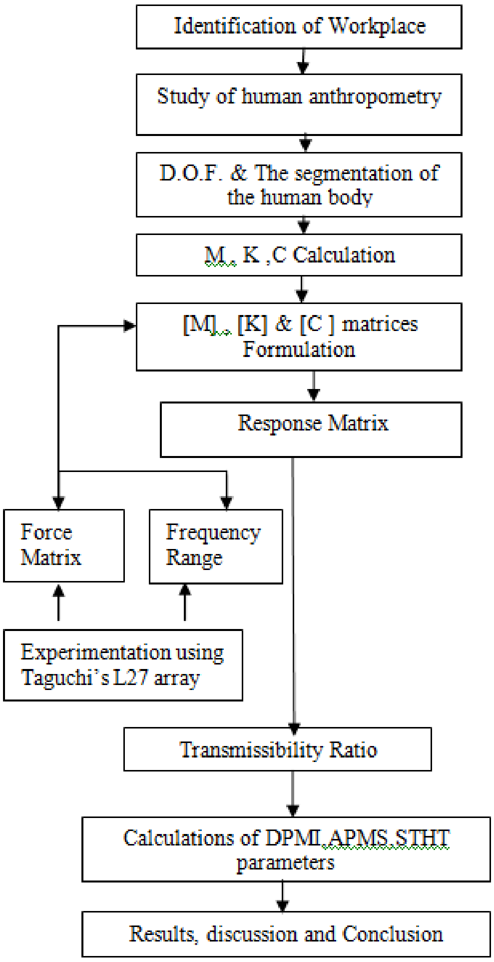

Fig.1: proposed methodology

PROPOSED METHODOLOGY TO FORMULATE THE MODEL

Our proposed model consist the human body in a sitting posture can be modelled as a mechanical system that is composed of several rigid bodies interconnected by springs and dampers. This model as shown in Fig. 2 consists of four mass segments consistent by four sets of springs and dampers. The four masses represent the following four body segments: the head and neck (m1), the chest and upper torso (m2), the lower torso (m3), and the thighs and pelvis in contact with the seat (m4). The mass due to lower legs and the feet is not included in this representation, presumptuous they have negligible contributions to the biodynamic response of the seated body. The stiffness and damping properties of thighs and pelvis are (k4) and (c4), the lower torso are (k3) and (c3), upper torsos are (k2) and (c2), and head are (k1) and (c1).

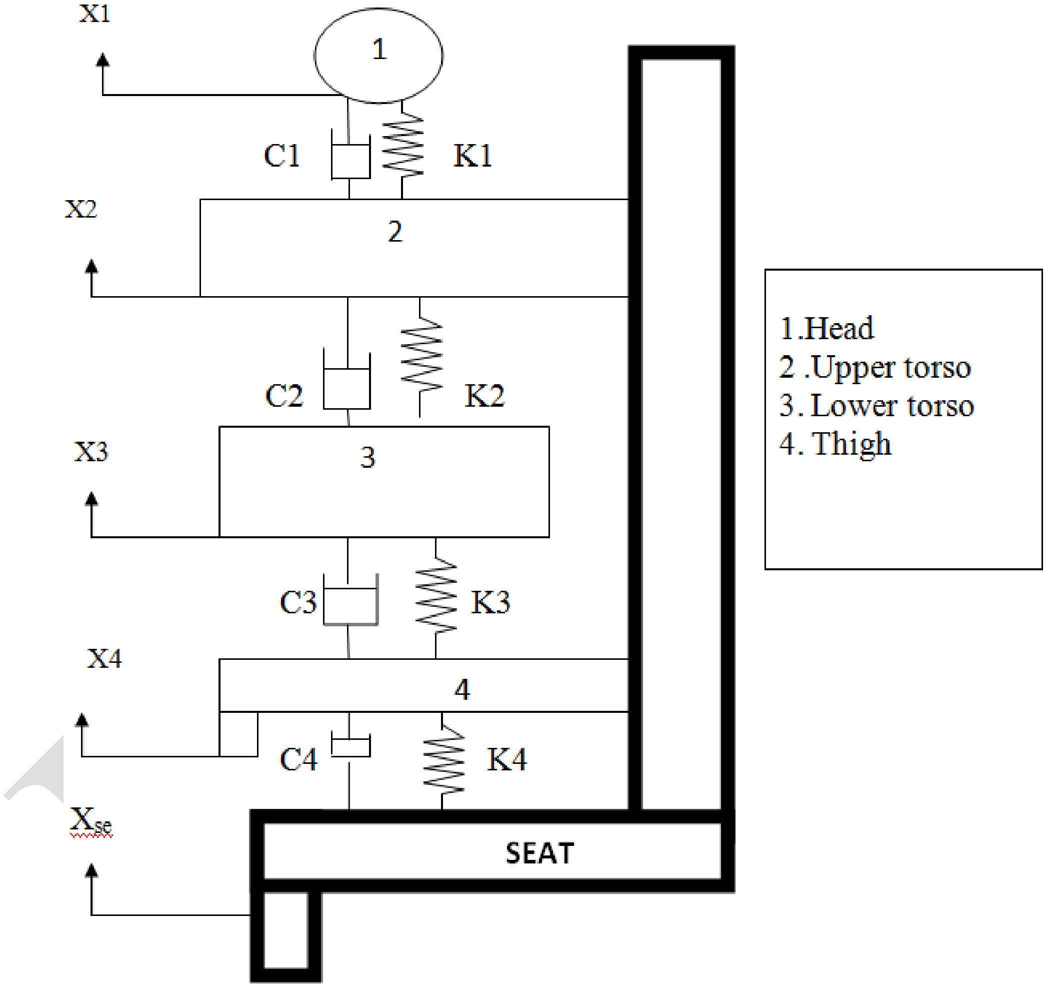

Fig2:Proposed 4 DOF vibratory model for the Driver sitting Posture.

By using proposal model, we obtain the equations of motion. The system equation of motion, for the model can be expressed in matrix form. The matrix form consist of M, K, C mass, stiffness ,damping matrices respectively that is force vector due to external excitation. By using Fourier transformation of equation an equation can be generated which is quiet useful to derive various parameters.

ASSUMPTION FOR THE MODEL

The biodynamic of seated human subjected to vertical vibration has been widely accessed in term of STHT, DPMI, and APMS. The first function refers to transmission of motion through body, whereas the other two pertain to force and motion at the point of vibration input to the body. In order to validate the model the data sets will conduct under following assumption.
1.A human subject is considering sitting without backrest support, irrespective of hands position.
2. Body masses will be limited to within 49-94 kg.
3. Feet are supported and vibrated.
4. Analysis is constrained to vertical direction.
5. Excitation frequency range is limited to 5-20Hz.

EXPERIMENTAL PLAN

To carry out the experiment we will use L27 Array as experimental plan .Execution of L27 will gives us the amplitude of excitation force and frequency range .This values are supplied to general equation for getting the various responses.L27 array is as follows,

Standard Experimental Plan (L27 Array)

Exp No	Speed	Road Profile	Distance	Air in the Rear Wheel	Exciting Frequency HZ
1	0	-1	0	-1	
2	1	1	0	0	
3	0	0	-1	-1	
4	0	-1	-1	0	
5	1	0	0	1	
6	1	0	-1	0	
7	0	0	-1	-1	
8	0	1	0	1	
9	-1	0	1	0	
10	-1	0	0	1	
11	0	-1	0	1	
12	0	1	-1	0	
13	1	0	1	0	
14	0	1	1	0	
15	0	1	0	1	
16	1	-1	0	0	
17	1	0	0	-1	
18	-1	-1	0	0	
19	0	-1	1	0	
20	0	0	0	0	
21	0	0	1	-1	
22	0	0	1	1	
23	-1	0	-1	0	
24	0	0	0	0	
25	-1	0	0	-1	
26	0	0	0	0	
27	-1	1	0	0	

Parameters Levels

Code	**-1**	**0**	**1**
Speed (Km/Hr)	20	40	60
Road Profile	Poor Surface (P)	Rough (R)	Smooth (S)
Distance between centre of Steering and the driver body CG	Min (A)	Medium (B)	Max (C)
Air in the all wheels	Min(L)	Average (M)	Max(H)

RESSPONCE MEASURE UNDER STUDY

The biodynamic response of a seated human body exposed to whole-body vibration can be broadly categorized into two types. The first category "To the-body" force motion interrelation as a function of frequency at the human-seat interface, expressed as the driving-point mechanical impedance (DPMI) or the apparent mass (APMS). The second category "Through-the-body" response function, generally termed as seat-to-head transmissibility (STHT) for the seated occupant.

1. **DPMI** :The DPMI relates the driving force and resulting velocity response at the driving point (the seat-buttocks interface), and is given by

$$Z(j\omega) = F(j\omega) / V(j\omega)$$

Where $Z(j\omega)$ is the complex DPMI , $F(j\omega)$ & $V(j\omega)$ are the driving force and response velocity at the driving point, $\boldsymbol{\omega}$ is the angular frequency in rad/ sec
Accordingly, DPMI for the model can be represented as:

$$\{DPMI(j\omega)\} = \left|(c4 + \frac{k4}{j\omega})(\frac{X_4(j\omega)}{X_0(\omega)}) - (c4 + \frac{k4}{j\omega})\right|$$

2. **APMS:**In a similar manner, the apparent mass response relates the driving force to the resulting acceleration response, and is given by

$$\{APMS(j\omega)\} = \frac{F(j\omega)}{a(j\omega)}$$

Where, $a(j\omega)$is the acceleration response at the driving point. The magnitude of APMS offers a simple physical interpretation as it is equal to the static mass of the human body supported by the seat at very low frequencies, when the human body resembles that of a rigid mass. The above two functions are frequently used interchangeably, due to their direct relationship that given by:

$$\{APMS(j\omega)\} = \frac{DPMI(j\omega)}{j\omega}$$

APMS for the model can be represented as:

$$\{APMS(j\omega)\} = \left| \left(\frac{c4}{j\omega} + \frac{k4}{-\omega^2}\right)\left(\frac{X_4(j\omega)}{X_0(\omega)}\right) - \left(\frac{c4}{j\omega} + \frac{k4}{-\omega^2}\right) \right|$$

3. STHT: The biodynamic response characteristics of seated occupants exposed to whole body vibration can also be expressed in terms of seat-to-head transmissibility (STHT), which is termed as "through-the-body" response function. Unlike the force-motion relationship at the driving-point, the STHT function describes the transmission of vibration through the seated body. The STHT response function is expressed as:

$$\{STHT(j\omega)\} = \frac{X_1(j\omega)}{X_0(j\omega)}$$

CONCLUSION

The work is conducted to increase the human comfort, high productivity, reduce injuries and various problems regarding body.
The model posture will show how the vibration is distributed to various part of body and at what frequency of excitation human feel discomfort able. The certain measure like DPMI, STHT, and APMS can be calculated. The driver comfort can increase by changing the stiffness Value of spring, seating arrangement.

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