Determination of Transmissibility Responses of Human Seated Body Exposed to Vibration

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Abstract - *To study the whole body vibration analysis for human body in sitting posture as human body suffers from health issues like lower back pain(spinal cord Related issues).long term exposure to vibration also can affect the whole body Performance and visual impairment of the driver and the main objective is to get The transmissibility response phase angle and to study how does it travels with the Amplify or behaviour of vibrations and how to simulate vibration of body of vehicle Using the Ansys software as the Ansys software is for the simulating the interactions Of disciplines of physics, structural, vibration, fluid dynamics and heat transfer. Driver seat is one of the main aspects to be considered while defining comfort in a moving vehicle. The current analysis concentrates on driver seat because driver comfort is of main concern since it is the most occupied seat in any vehicle and the occupancy is for longer duration. In addition to sitting, the driver job is to manipulate different controls and concentrate parallel on many aspects. The research work aims at studying the vertical vibrations transferred to the human body via seat. The work is an attempt towards studying dynamic characteristics of driver seat for comfort through objective evaluation. For objective evaluation, two tests were conducted Seat Effective Amplitude Transmissibility (SEAT) test and Ride Comfort Index test under two different conditions.*

***Key Words*: Biodynamic model & vehicle mode, The values of equivalent mass, equivalent stiffness & equivalent damping, STH, DPM & IM, AP, Transmissibility, RTLT, RTV, RTUT, RTH.**

1. INTRODUCTION

The Vibration is a movement of an object in oscillatory motion. All of the object that content elasticity a mass elements are capable of vibration. Vibration of the vehicle can cause various effect on the structure within the body such as organ, body tissues, and systems of the individual as the vibration is transmitted from the vehicle seat to a person body. Human body suffers from health issues like lower back pain, motion sickness, digestive system problems during long-term exposure to whole-body vibration (WBV). Variety of activities on daily basis like travelling in bus, car, train, ship, airplanes give rise to WBV. In agricultural operations, human body is exposed to low-frequency vibration. The main reason of vibration is agricultural slow speed operations in rough terrain and rigid construction of equipment. In seated posture, human body is most sensitive to low-frequency vibration and these frequencies have been considered to be critical among human body because of low natural resonance frequency of human body. The biodynamic response characteristics of seated subjects exposed to vibration have been extensively reported in terms of apparent mass (APMS). The aim in this paper is to propose a comparison of mathematical models for the driving point apparent mass of the seated human body. mechanical impedance of the human body could be represented by a discrete system of masses, springs and dampers or a distributed parameter model. To describe the driving point apparent mass over the frequency range of interest, it can be ignored the motions of body parts which do not contribute to the driving point apparent mass. Therefore, the number of degrees of freedom, required in a model, depends on this objective. Seat transmissibility, obtained with human subjects, can be computed by single–degree–of–freedom or two–degree–of–freedom response in the human body.

1.1 Background

There are two types of vibration that occurs on the vehicle, free vibration and force vibration. Free vibration occurs when the vehicle is passing the non-rough road surface and the vibration may gone as a result of the dispersion of the energy in damping. Then the force vibration occurs when the road is rough and the disturbance continuously occur as the vehicle pass the obstacles.

1.2 Problem Statement

Whole body vibration analysis for human body in sitting posture.

As human body suffers from health issues like lower back pain (spinal cord related issues). Long term exposure to vibration also can affect the body performance and visual impairment of the driver.

1.3 Goals & Objectives

The main objective is to get the transmissibility response phase angle.

To study how does it travels with the amplify or behaviour of vibrations.

1.4 Scope & Major Constraints

This project is to stimulate vibration body of vehicle using the ANSYS software. As the Ansys software is for the stimulating the interactions of disciplines of physics, structural, vibration, fluid dynamics, heat transfer and electromagnetic.

1.5 Expected Outcomes

Whole body vibrations on different kind of two wheelers i,e bike, moped, cruiser, sport bike can be studied and different model for each one can be predicted. Based on this response of human can be studied for each different type of motorcycle. These models can also be verified with actual experimental results.

2. Literature Review

Raj Desai, Anirban Guha, P. Seshu [1] Operators of the vehicles and heavy earth moving machinery are continuously exposed to low frequency whole-body vibration (WBV) of comprehensive magnitudes arising from tire/track-terrain interactions. Research studies shown a high presence of back disorders such as disc degeneration, muscular pain, among the occupational vehicle drivers subjected to whole-body vibration. The modelling and measurement of the biodynamic response of human body is major research topic, with applications to ergonomics, paasive or active suspension control system technologies, adverse effects on the human body that causes discomfort and some health issues. The risk of the vibration exposure depends on three different factors: the time span, the amplitude and the frequency of the transmitted vibration. In the field of automotive engineering, manufacturers and designers require to understand how the acceleration signals are amplified or damped by the human-seat interface in order to increase human comfort. Most of human body models reported in literature are lumped parameter. The limitation with lumped parameter model is that they can be analysed in one direction only. Human body is having complex motion so minimum two dimensional (2D) model need for analysing human body response. The models considered two objective functions with considering vertical or fore and aft vibrations. Multibody human body models of 20 degree of freedom (DOF) developed for seated human, and model parameters are optimized using genetic algorithm (GA) for published experimental data from literature. Model is able to match the published experimental data for Seat to Head Transmissibility (STHT) and Apparent Mass (AM) Neil J. MANSFIELD and Setsuo MAEDA2 [2] Occupational exposure to whole-body vibrationis often combined with a requirement to perform twisting actions. This paper reports a study where the effect of twisting on the biomechanical response of the seated person was investigated. Twelve male subjects were exposed to vertical random whole-body vibration at 0.4 m/s2 r.m.s. Each subject sat in four different postures: 'back-on', 'backoff', 'twist' (where subjects were required to twist the torso by 90°) and 'move' (where subjects were required to performing a moving task with extended arms). Similar apparent masses were measured for the 'back-on', 'back-off' and 'twist' conditions, where a peak occurred at about 6 Hz. For the 'move' condition, the peak in the apparent mass was attenuated indicating a different biomechanical response in this posture. The 6 Hz peak in fore-and-aft cross-axis apparent mass was eliminated in the 'move' condition. It is suggested that the change in biomechanical response is due to either the extended arms acting as a passive vibration absorber or that the twisting action interferes with the usual acceleration-muscle feedback system. Further work will be required to test these hypotheses.

Zengkang Gan 1 , Andrew J. Hillis1 , Jocelyn Darling1[3] In this paper, a lumped-parameter biodynamic model of a seated human body (SHB) exposed to low frequency whole-body vibration in both vertical and fore-and-aft directions is developed. The model is based on all three types of biodynamic functions: seatto-head transmissibility (STHT), driving-point mechanical impedance (DPMI) and apparent mass (APM). The objective of this work is to match all three functions and to represent the biodynamic behaviour of the SHB in a more comprehensive way.

Three sets of synthesized experimental data from published literature are selected as the target values for each of the three biodynamic functions. A curve fitting method is used in the parameter identification process which involves the solution of a multivariable optimization function comprising the root mean square errors between the computed values using the model and those target values. Finally, a numerical simulation of the frequency response of the model in terms of all three biodynamic functions has been carried out. The results show that an improved fit is achieved.

S. Prashanth, N. V. Amar Kishore, V. H. Saran, S. P. Harsha [4] Humans are more sensitive to whole Body Vibration under low frequency range. Under this frequency range human feels more discomfort. Due to this reason more research is going on from more number of years in low frequency range. As a part of research biodynamic models are prepared to number of degrees of freedom and these results are compared with the experimental data. In the present study the authors prepared a 5 DOF biodynamic model of the human body in a sitting posture without backrest under sinusoidal excitation to determine the. dynamic response characteristics such as Driving point mechanical impedance (DPMI)which describes the "to-the–body "force motion relationship at the seat to human interference and Transmissibility function describes the "through–the-body" vibration transmission properties. As a part of this study analytical transmissibility data is validated with the experimental data. The resonant frequencies of the human subjects computed on the basis of Transmissibility function are found to be within close to that of the expected for the human body.

Graziella Aghilone1 Massimo Cavacece2 [5] In this study, the Authors propose the discussion of nonlinearity of the human body's dynamic response. The variables that affect nonlinearity of the human body's dynamic response in the experimental measurements can be distinguished in two categories: intrinsic variables, relating to the individual subjects; and extrinsic variables, relating to the experimental conditions. International Standard 5982 : 2002 gives idealized values for the apparent mass and the seat–to–head transmissibility of seated people exposed to vertical vibration. The values are intended for the development of mechanical models to represent the body. Many mathematical models of the vertical apparent mass of the seated human body are developed. Single and two–degree–of–freedom models obtain a good agreement with experimental seat transmissibility by nonlinear least squares method and Trust–Region algorithm. The comparison between single and two–degree–of– freedom models by goodness-of-fit statistics suggests that two–degree–of–freedom model is recommended for best results.

Purnendu Mondal * and Subramaniam Arunachalam [6] The comfort level of the human occupant inside a dynamic vehicle is dependent on the level of vibration generated inside the different segments of the human body. Some technologies have been developed to provide the final level of vibration inside an automotive-seated human, but those technologies considered only a specific portion of human segments. In the present work, a unique and comprehensive finite element simulation model was proposed to predict the final level of vibration at different segments of a seated human driver inside a moving car. The main aim of this unique simulation methodology was to replace the time-consuming and expensive real life vibration testing for a car-seated human body, with a non-robust and correctly postured virtual human model in a finite element environment. The output of this research work focused on the vertical accelerations, vertical displacement, and frequency, and the results obtained from this research work were validated through comparison to real life test data and information provided in other similar research works. The validation study showed that this unique simulation methodology can successfully be implemented to anticipate accelerations and frequencies at different points of a car-seated human body in order to optimize human health, comfort, and safety.

Ishbir Singha, S.P. Nigamb,1 and V.H. Saranc,2 [7] Need and importance of modelling in human body vibration research studies are well established. The study of biodynamic responses of human beings can be classified into experimental and analytical methods. In the past few decades, plenty of mathematical models have been developed based on the diverse field measurements to describe the biodynamic responses of human beings. In this paper, a complete study on lumped parameter model derived from 50th percentile anthropometric data for a seated 54- kg Indian male subject without backrest support under free un-damped conditions has been carried out considering human body segments to be of ellipsoidal shape. Conventional lumped parameter modelling considers the human body as several rigid masses interconnected by springs and dampers. In this study, concept of mass of interconnecting springs has been incorporated and eigenvalues thus obtained are found to be closer to the values reported in the literature. Results obtained clearly establish decoupling of vertical and fore-and-aft oscillations.

Santosh MANDAPURAM1, Subhash RAKHEJA1, Paul-Émile BOILEAU2, Setsuo MAEDA3 and Nobuyuki SHIBATA3 [8] The apparent mass and seat-to-head-transmissibility response functions of the seated human body are investigated under exposures to fore-aft (x), lateral (y), and combined fore-aft and lateral (x and y) axis whole-body vibration. The experiments were performed to study the effects of hands support, back support and vibration magnitude on the body interactions with the seat pan and the backrest, characterised in terms of fore-aft and lateral apparent masses and the vibration transmitted to the head under single and dual-axis horizontal vibration. The data were acquired with 9 subjects exposed to two different magnitudes of vibration applied along the individual x- and y- axis (0.25 and 0.4 m/s2 rms), and along both the-axis (0.28 and 0.4 m/s2 rms) in the 0.5 to 20 Hz frequency range, and analyzed to derive the biodynamic responses. A method was further derived to obtain total seated body apparent mass response from those measured at the backrest and the seatpan. The results revealed coupled effects of hands and back support conditions on the responses, while the vibration magnitude effect was relatively small. For a given postural condition, the biodynamic responses to dual-axis vibration could be estimated from the direct- and cross-axis responses to single-axis vibration, suggesting weakly nonlinear behaviour.

Shantanu Rohidas Tathe M Tech (Auto. Tech.), CoEP-ARAI Academy Kiran P Wani Faculty, ARAI Academy [9] Whole body vibration deals with the biodynamic responses of human body in various postures. Vertical vibration exposure in sitting posture is common situation encountered while driving vehicle or riding motorcycle. We have chosen Wan & Schimmel's 4 DOF biodynamic model for this study by referring the goodness of fit results for various models available in the literature. A single degree of freedom model of motorcycle is used for analysis of whole body vibration on two wheeler. We have neglected pitch, yaw movements of two wheeler for purpose of simplicity. Whole body vibration analysis for human body in sitting posture is described by three terms i.e. Seat to Head Transmissibility (STH), Driving point impendence (DPM) & apparent mass (AP). In order to analyze human response on motorcycle Road to head (RTH), Road to lower torso (RTLT), Road to viscera (RTV), Road to upper torso (RTUT) responses are calculated for different motorcycle suspension natural frequencies. Simulation of biodynamic model is carried in MATLAB which shows close match with experimental results from literature. Analysis shows that peak values occur at 3.97 Hz, 6.77 Hz & 3.24 Hz for STH, DPM & AP respectively. For 4 Hz suspension natural frequency of motorcycle, most severe RTH, RTUT, RTV, RTLT responses are noted. These responses are severe in the two wheeler suspension natural frequency range of 3.5 Hz to 5.5 Hz. This study will help in better design & also in improving the ride & handling performance of two wheeler.

E. DIECO MERCERAT', KEES WAPENAAR, JACOB FOKKEMA and MENNO DILLEN [10] Mercerat, E.D., Wapenaar, C,P.A., Fokkema, J.T. and Dillen, M., 2002. Scaling behaviour of the acoustic transmission response of Rotliegend sandstone under varying ambient stress. In: Fokkema, J. T. and wapenaar, C. P. A. (Eds.), Integrated 4D Seismics. Jorrna I oÍ Seismíc Exploration, lli 137' 158. Ultrasonic experiments carried out on Rotliegend reservoir sandstone samples have shown a specific stress-dependent behaviour of the transmission response. Apart from the well-known velocity increase as ambient stress iÍEreases, the amplitude and the time are scaled when the stress is changed from one value to another. Our hypothesis is that when stress changes, some mineralogical constituents of the rock may change their acoustic properties differently from other constituents. As a consequence, different scattering attenuation effects take place within the rock. The observed stress-dependent scaling behaviour can be a consequence of the latter phenomenon. In order to quantity the scaling behaviour, two approaches arc used. First, a heuristically derived model from the experimental data is tested on numerically simulated data. Next, an analytically derived model from a modified version of the O'Doherty-Anstey expression for the transmission response through finely layered media is also analyzed and tested both on numerically simulated and experimental data. Both scaling models present two scalar parameters that relate a wavelet recorded at a high ambient stress with another recorded at a relatively low stress. Estimating these parameters from measurements for a range of different ambient stresses gives valuable information about the stress-dependent behaviour of the reservoir rock.

Rohit Kumar, Ishbir Singh, Sachin Kalsi [11] Human subject suffers from many problems when it comes into contact with conditions of vibrations while travelling, working etc. in sitting posture. This result into a headache, body ache, increase in heart rate etc., therefore it becomes necessary to study the Whole body vibrations effect on human subject. Taking this into investigation, a current study has been conducted to discover the vibration effect on human subject using three different CAD models i.e. 54 kg ellipsoidal model, 76 kg solid model (single layer) and 76 kg 3-layer CAD model. All these CAD models have been modelled using 50th percentile for 54 kg and 95th percentile for 76 kg anthropometric data of Indian male population with reference from existing literature. The boundary conditions have been considered as per real conditions for different vibration conditions in sitting posture. Current study has been conducted to evaluate the mode shapes corresponding to natural frequency of each CAD model to observe the response of human subject in WBV. The comparisons of results obtained from all these CAD models have been done and it's found that maximum deformation is obtained in head. It has been observed from the results that with a rise in natural frequency of any of the biodynamic CAD model, deformation also gets increase and also, 3- layer model found to be best model for studying the effect of WBV on human subject. The results of all CAD models have been compared and validated with the existing literature.

W. Wanga , S.Rakhejaa,, P-E´.Boileaub [12] The "to-the-body" and "through-the-body" biodynamic response functions of the seated human body exposed to vertical vibration are measured and analyzed in an attempt to identify relationships between the apparent mass and seat to-head transmissibility measures. The experiments involved 12 male subjects exposed to three magnitudes of whole-body vertical random vibration (0.25,0.5,1.0 m/s2 rms acceleration) in the 0.5–15 Hz frequency range, and seated with three back support conditions (none, vertical and inclined), and two different hands positions (hands in lap and hands on the steering wheel). The vertical apparent mass and seat-to-head transmissibility responses were acquired during the experiments, where the head acceleration was measured using a light and adjustable helmet-strap mounted accelerometer. The results showed that both the measured responses show good agreements in the primary resonances, irrespective of the back support condition, while considerable differences between the normalized apparent mass and seat-to-head transmissibility could be seen in the secondary resonance range for the two back supported postures. The seat-to-head transmissibility responses are further shown to be relatively sensitive to back supported postures compared with that of apparent mass responses. Relatively stronger effects of hands position were observed on the seat-to-head transmissibility responses compared with the apparent mass responses under back supported conditions. From the results, it is further concluded that seat-to-head transmissibility emphasizes the biodynamic response in the vicinity of the secondary resonance compared to the apparent mass. The seat-to-head transmissibility measure is thus considered to be more appropriate for describing seated body response to higher frequency vibration.

Simona Rodean1, Mariana Arghir1, Claudiu Paul Rodean2 , and Cristian George Rodean2 [13] Ina seated posture into an autovehicle, humans are most sensitive to whole-body vibrations under low-frequency excitation. This research is focused only on the effect of the backrest angle on the biodynamic response functions. In this paper there are present the results of investigations for 10 participants, whose mean body mass was 61.4 kg. For the biodynamic responses of a seated human body subjected to vertical vibrations, three automotive postures was study: without backrest support, with backrest inclined 7 and respectively 15, by measurement of transmitted vibration in two different situations: with belt and respectively without this. Knowledge of human responses to vibration provides information about the position of backrest support to mitigate vibration transmitted through the body ensuring the health, comfort and performance.

Arvinder Singh1, Ishbir Singh1, Sachin Kalsi1[14] The aim of present study is to evaluate the effect of whole-body vibration on various human body segments. A three-layer 3D CAD model has been modelled according to Indian human male anthropometric data with three different layers for defining the properties of human bone, skin and muscles, respectively. Human model has been excited at RMS value of 0.5, 1.0 and 1.5 m/s2 in a frequency range from 0 to 20 Hz. Human subject has been considered to be in sitting posture while driving a tractor. The effect in terms of seat to head and feet to head transmissibility has been evaluated. It has been found that 4–6 Hz frequency range is dominating in both evaluations with maximum effect on head.

Sattar Ghasemi-Goneyrania, Ali Malekib [15] Biomechanical modelling of human body has been of great importance in industry, since human body is vulnerable to vibration and chronic exposure to vibration is the culprit behind a great deal of illnesses. biomechanical modelling is based on experimental data and the aim is to create a design basis for vehicles and other stuff in contact with human body. In the present article, information about 3 independent lumped-parameter models and some models which were result of multi-objective optimization of independent models, are gathered and analysed. Multi-objective optimization is a novel approach, usually deploying genetic algorithms and results of analyzing models in this study suggest that optimization does not necessarily mean improvement. In this study, we numerically simulated above-mentioned models and validated their fitness to experimental data. Final results have proven that 7 degrees of freedom model proposed by Marzbanrad and Afkar is the best fitted model and can be used in industry as a basis for study of human body exposed to random.

3. METHODOLOGY

3.1 BIO-DYNAMIC MODEL & VEHICLE MODEL

For finding biodynamic responses of the model mass and geometric parameters of the model are required. In this study these parameters are taken from available literature.

Table 3.1 Model Parameters for Wan & Schimmels 4 DOF Model

Mass (kg)	*Damping (N-s/m)*	*Stiffness (N/m)*
$m_1=31$	$C_1=2475$	$K_1=49340$
$m_2=5.5$	$C_2=330$	$K_2=20000$
$m_3=15$	$C_3=200$	$K_3=10000$
$m_4=4.17$	$C_4=250$	$K_4=134400$
	$C_{31}=909.1$	$K_{31}=192000$

Where,

m_1= *mass of lower torso*

m_2= *mass of viscera*

m_3= *mass of upper torso*

m_4= *mass of Head & neck*

c_1= *damping coefficient between lower torso & viscera*

c_2= *damping coefficient between viscera& upper torso*

c_3= *damping coefficient between upper torso& viscera*

c_4= *damping coefficient between upper torso & Head & neck*

c_{31}= *damping coefficient between upper torso & lower torso*

k_1= *stiffness between lower torso & viscera*

k_2= *stiffness between viscera& upper torso*

k_3= *stiffness between upper torso & viscera*

k_4= *stiffness between upper torso & Head & neck*

k_{31}= *stiffness between upper torso & lower torso*

In the vehicle model, the equivalent stiffness includes the stiffness In of the tires, struts, and rider. The equivalent damping constant includes the damping of the struts. The equivalent mass includes the masses of the wheels, vehicle body, and the rider. When the equivalent values of the mass, stiffness, and damping of the system are used, we obtain a single-degree-of-freedom model of the motorcycle with a rider as indicated in fig.3.2.

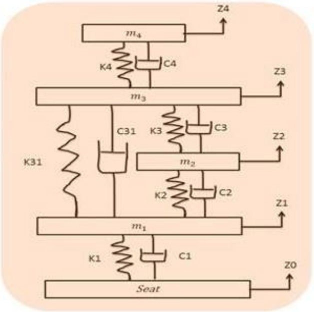


Fig.3.1 Wan & schimmel's 4 DOF model

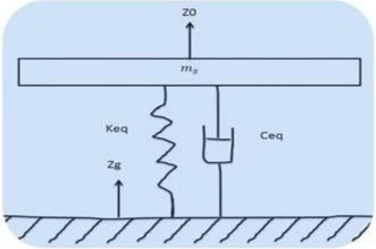


Fig.3.2 Single Degree of freedom model formotorcycle

The values of equivalent mass, equivalent stiffness and equivalent damping are calculated using following formulae.

$$m_{eq} = m_s + m_r \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$K_{eq} = \frac{K_f * k_{ft}}{k_f + k_{ft}} + \frac{K_r * k_{rt}}{k_r + k_{rt}} \ldots\ldots\ldots\ldots\ldots (2)$$

$$C_{eq} = c_f + C_r \ldots\ldots\ldots\ldots\ldots (3)$$

Where,

m_{eq} = *equivalent mass of vehicle*

m_s = *spring mass of vehicle*

m_r=*mass of rider*

k_f = *stifness of front suspension*

k_r = *stiffness of rear suspension*

k_{ft} = *stifness offront tire*

k_{rt} = *stiffness of rear tire*

C_f = *front strut damping coefficient*

c_r = *rear strut damping coefficient*

K_{eq} = *equivalent stifness of motorcycle*

3.2 EQUATIONS OF MOTION Biodynamic Model Equation

Considering Wan & Schimmel's 4DOF model as shown in figure 1, following equations are developed [2,3]

$$m_1\ddot{z} + c_1(\dot{z}_1 - \dot{z}_o) + c_{31}(z_1 \dot{-} \dot{z}_2) + c_2(\dot{z}_1 - \dot{z}_2) + k_1(z_1 - z_0) + k_{31}(z_1 - z_3) + k_2(z_1 - z_2) = 0 \ldots\ldots\ldots\ldots (4)$$

$$m_2\ddot{z} + c_2(\dot{z}_2 - \dot{z}_1) + c_3(z_2 \dot{-} \dot{z}_3) + k_2(\dot{z}_2 - \dot{z}_1) + k_3(z_3 - z_3) = 0 \ldots\ldots\ldots\ldots (5)$$

$$m_3\ddot{z}_3 + c_{31}(\dot{z}_3 - \dot{z}_1) + c_3(z_3 \dot{-} \dot{z}_2) + c_4(\dot{z}_3 - \dot{z}_4) + k_{31}(z_3 - z_1) + k_3(z_3 - z_2) + k_4(z_4 - z_4) = 0 \ldots\ldots\ldots\ldots (6)$$

$$m_4 z_4 + c_4(\ddot{\dot{z}}_4 - \dot{z}_3) + k_4(z_4 - z_3) = 0 \ldots\ldots\ldots\ldots (7)$$

Where ,

z_0 = ***Seat displacement***

z_1 = ***Lower torso displacement***

z_2 = ***Viscera displacement***

z_3 = ***Upper torso displacement***

z_4 = ***Head & neck displacement***

Vehicle Model Equation

Considering single DOF Model as shown in figure2

$$m_{eq} z_o^{\cdot\cdot} + C(\dot{z}_0 - \dot{z}_g) + k_{eq}(z_o - z_g) = 0 \ldots\ldots\ldots\ldots (8)$$

Where

z_g = ***Ground excitation displacement***

BIODYNAMIC RESPONSE

For evaluating the biodynamic response of human body model STH,IM and AP is considered.

3.3 SEAT TO HEAD TRANSMISSIBILITY(STH)

STH transmissibility is defined as the ratio of output responses at head to input excitation at seat

$$\text{STH} = \frac{Z_4(\omega)}{Z_0(\omega)} \ldots\ldots\ldots\ldots (9)$$

Where,

$Z_4(\omega)$ = *output response at output psoition*

$Z_0(\omega)$ = *input excitatio*

3.4 Drive point Mechanical Impendence (DPM or IM)

It is defined as the ratio of driving force (summation of spring and damping forces between pelvis and seat) to the driving point velocity (input velocity of the seat).

$$IM = \frac{F(f)}{V(f)} \ldots\ldots\ldots\ldots (10)$$

$$\text{IM} = \frac{(K_1 + j_\omega c_1)(z_0(\omega) - z_1(j\omega))}{j\omega z_0(\omega)} \ldots\ldots\ldots\ldots (11)$$

Where,

F(f)= force at frequency

V(f)= velocity at frequency

Z(ω)=output displacement amplitudes at mass m1

3.5 Apparent Mass (AP)

Apparent Mass for the human body is defined as the force required to accelerate the supporting surface & it is a complex function of frequency. It is defined as

$$AP = \frac{F(f)}{a(f)} = |\frac{IM}{j\omega} \ldots\ldots\ldots\ldots (12)$$

Where ,

AP= apperent mass

a(f)= acceleration frequency

Apparent mass is usually calculated in frequency domain. The unit of apparent mass is in kg.

3.6 Transmissibility

The combined effect of biodynamic model and vehicle model is considered while finding the response of system. Transmissibility is defined as the ratio of output responses to input excitation. Transmissibility is defined as

$$TR = \frac{Z_0(j\omega)}{Z_i(\omega)} \ldots\ldots\ldots\ldots (13)$$

Where,

Z_0 = *output response*

$Z_i(\omega)$ = *input excitation*

Transmissibility are defined for lower torso (RTLT), viscera (RTV),upper torso (RTUT) & head and neck (RTH).

$$RTLT=\frac{Z_1(j\omega)}{Z_i(\omega)} \quad \ldots\ldots (14)$$

$$RTV=\frac{Z_2(j\omega)}{Z_i(\omega)} \quad \ldots\ldots (15)$$

$$RTUT=\frac{Z_3(j\omega)}{Z_i(\omega)} \quad \ldots\ldots (16)$$

$$RTH=\frac{Z_4(j\omega)}{Z_i(\omega)} \quad \ldots\ldots (17)$$

3.7 VALIDITY OF BIODYNAMIC MODEL

It is must to check the validity of any model otherwise it is not reliable. Validity is checked in terms of goodness of fit.

$$\epsilon = 1 - \frac{\sqrt{\sum\frac{(t_m-t_e)^2}{N-2}}}{\frac{t}{N}} \quad \ldots\ldots (18)$$

Where,

$t_m = test\ datum$
t_e= *calculated parameter*
N =number of test points

4.0 Implementation Design

The bio-dynamic model for seated posture is considered and subjected to vertical vibration. With the help of this mathematical model STH transmissibility, DPM impedance, and AP mass is evaluated. STH gives transmissibility from seat to head. DPM impedance and AP mass refers to the relation of force and velocity and force of acceleration of the body respectively. So these are the following assumption were considered while modeling.
A human body is considered sitting without backrest support, irrespective of the hand's position.
Body masses will be limited within 49-90 kg
Feet are supported and vibrated
Analysis is constrained to the vertical direction

Excitation frequency range is limited to 0.5-20 Hz Vibration excitation amplitudes are below 5 m/s2, with the nature of excitation specified as being either sinusoidal or random.

Fig.4.1
Skin

Fig.4.2
Bone

Fig.4.3
Muscle

5.0 Result and Analysis

5.1 Results

For the analysis of human body vibration on two wheeler, one DOF model is used. For more realistic and accurate results this model can be refined and more DOF can be considered. Effect of bouncing & pitching simultaneously on human can be studied by more complex motorcycle model.
Simulation results of biodynamic model shows close match with experimental results & similarly simulation results for coupled model of human and vehicle can be verified with the actual experiments conducted in field. This will give the accuracy & validity of the combined model. Based on the actual results, model can be refined again to best fit the experimental results and more realistic model for rider with motorcycle can be formed.
Whole body vibrations on different kind of two wheelers i.e bike, moped, cruiser, sport bike can be studied and different model for each one can be predicted. Based on this response of human can be studied for each different type of motorcycle. These models can also be verified with actual experimental results.

5.2 Analyzing Seat Vibration Data Using MATLAB

This case study analyzes the amount of vibration a passenger experiences for a vehicle traveling over a road disturbance (bump). We want to determine the amount of reduction in displacement and acceleration that can be achieved using two different controllers. We have test data across 12 vehicle speeds for three schemes:

Baseline Suspension System (uncontrolled)

Controller 1: Actively Controlled Seat + Suspension System

Controller 2: Low Cost Version of Controller 1

The primary difference between the two controllers configurations are the implementation of the linear motor used to dampen oscillations in the seat. The dynamic range of the linear motors is:

Controller 1: +/-100 N

Controller 2: +/- 10 N

Contents

Load Seat Vibration Data and Remove Undesired Noise

Estimate Controller Performance

Model Controller Acceleration

Load Survival Data and Visualize

Analysis of Variance (ANOVA)

Perform Weibull Analysis on Survival Data

Compare Survival Times for Each Controller

5.3 Load Seat Vibration Data and Remove Undesired Noise

The first step in our analysis is to load the data from Excel Spreadsheet files and filter out any noise not related to the seat vibration dynamics. We use the filter we defined using the Filter Design and Analysis Tool and the M-Function (get Seat Data) to import, filter, and plot the data.

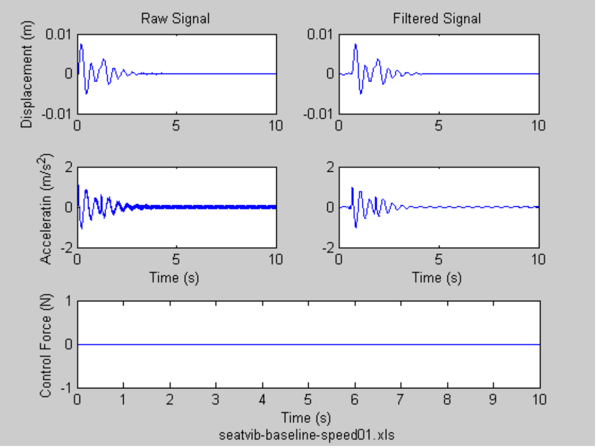


Fig.5.1

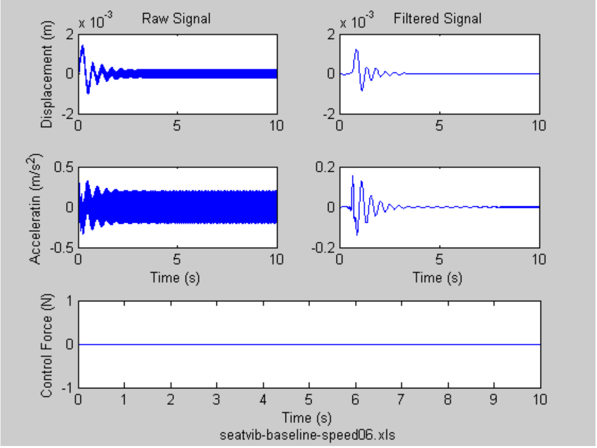
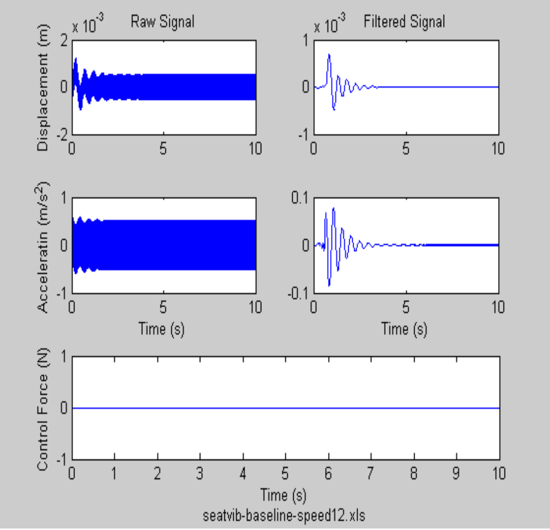


Fig.5.2



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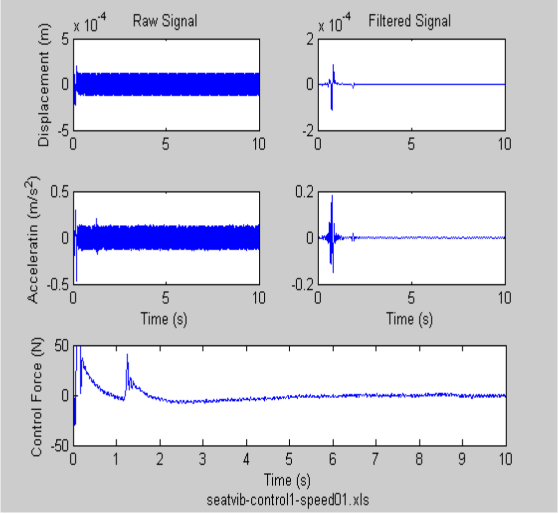

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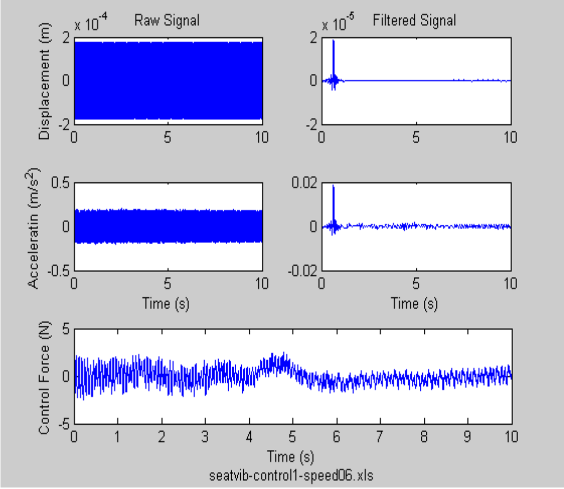
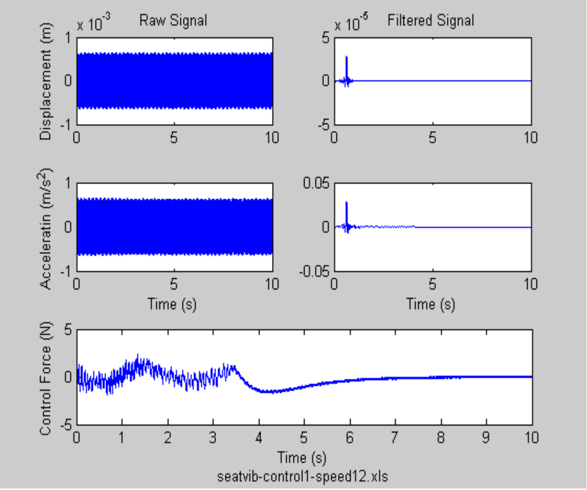


Fig.5.5



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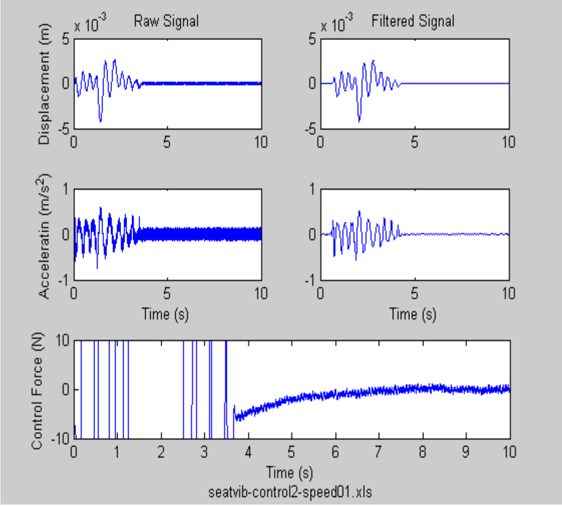

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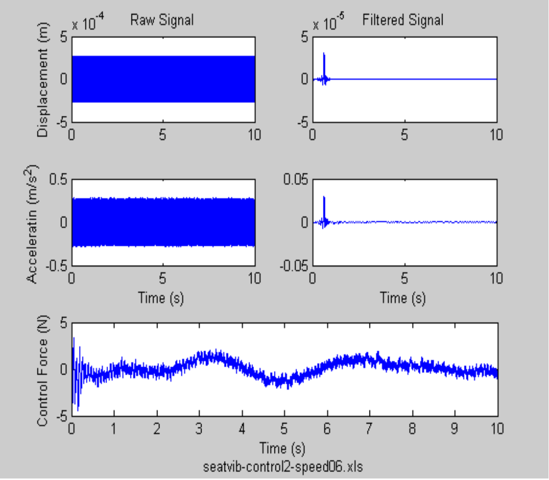


Fig.5.8

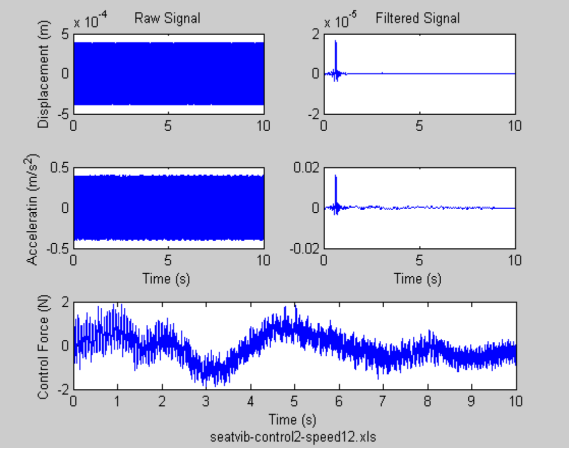


Fig.5.9

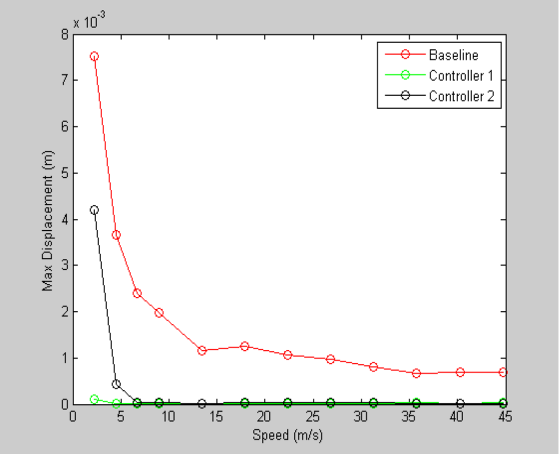


Fig.5.10

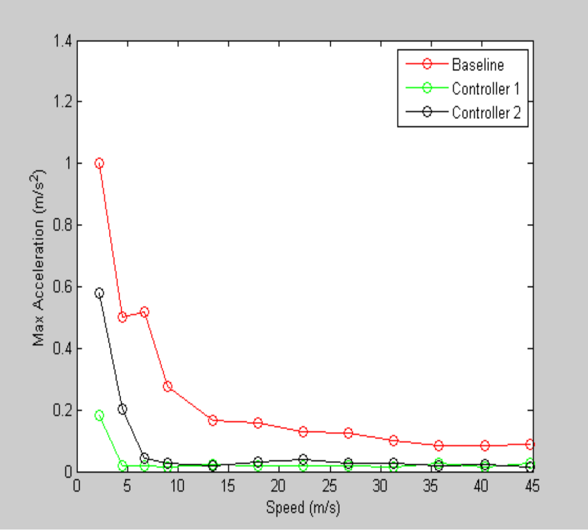


Fig.5.11

Looking at displacement and acceleration, we see that Controller 1 and 2 are different primarily at low speeds and are similar at high speeds. We need to determine if this difference is significant and not a result of measurement error or noise.

5.4 Model Controller Acceleration

We want to determine if the difference in the two controllers are significant in terms of the acceleration observed. The acceleration curves for both controllers appear to be similar and are significantly different at the low speed range. Let's determine if a single model captures both trends with only a change in one parameter. The model we will fit is

$$y=a*x_1^{b+c*x2}+d$$

where x1 is speed and x2 is a binary variable representing the different configurations (0 for Controller 1, 1 for Controller 2).

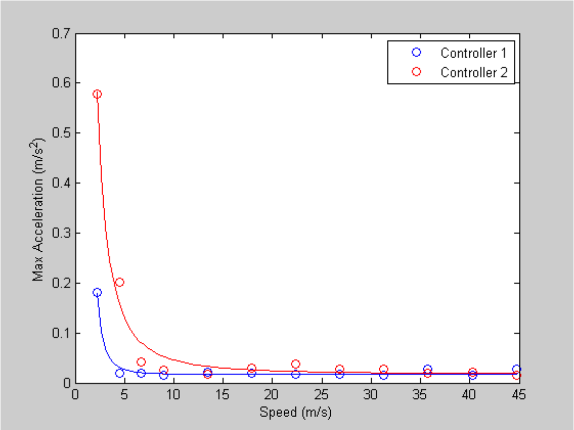


Fig.5.12

Note that the confidence interval for 'c' does not include 0, so the difference between Controllers is significant and not a result of noise or measurement error. At this point, Controller 1 has the best overall performance. However, if we are only concerned with the performance at moderate to high speed (>10 m/s) either configuration will be acceptable. Controller 2 has considerable cost advantage and we don't want to rule it out at this point.

Review of the controller force shows that Controller 2 is saturated (max force) over the low speeds. This is a concern from a reliability point of view. With a saturated controller, we may run the risk of early failure and need to quantify if this will have an impact on our selection of controllers. For our intended application, **we need to have >90% survive at least 1,000 hours**.

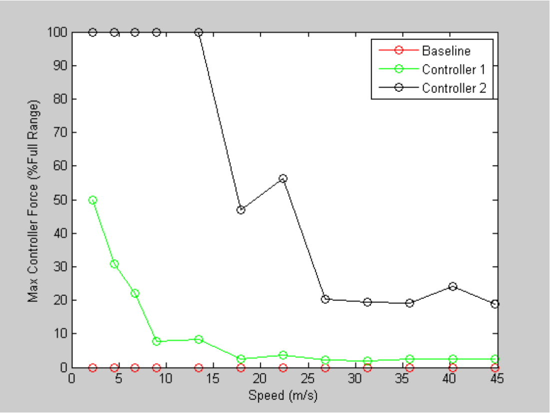


Fig.5.13

5.5 Load Survival Data and Visualize

To gain insight into the reliability of our two controller configurations, we tested 20 of each until failure. The test consisted of the entire seat and controller assembly and cycled under worst case conditions. The data was saved in an Excel Spreadsheet as the number of hours the assembly was tested before failure.

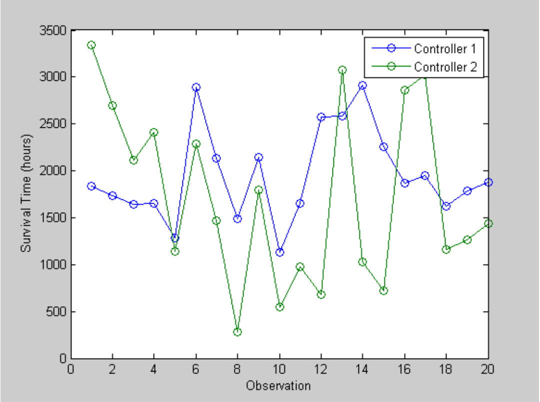
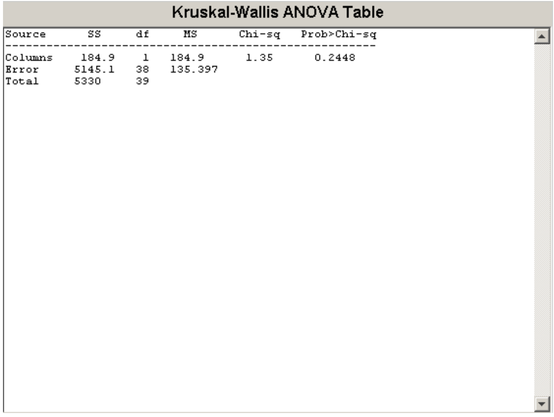


Fig.5.14

The average values of the two configurations are similar in magnitude. In order to determine if the difference is real, and not a result of our sample size, we'll perform an Anslysis of Variance test to determine if the average values are statistically different.

5.6 Analysis of Vairance (ANOVA)

ANOVA is an analysis technique that allows us to test for differences in means across groups of data. We'll use ANOVA to test if the difference in means is actually different given our small sample size.



```
Source        SS      df      MS        Chi-sq   Prob>Chi-sq
------------------------------------------------------------
Columns      184.9     1    184.9       1.35       0.2448
Error       5145.1    38    135.397
Total       5330      39
```

Fig.5.15

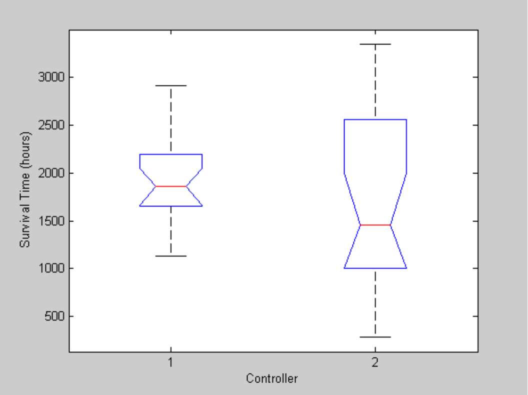


Fig.5.16

The p-value from the ANOVA table is around 0.25. This result indicates that the mean failure rates are not significantly different. While the mean failure rates cannot be declared different, we need to understand how the data differs in its distribution. The box plot shows us that Controller 2 has a wider dispersion of data. We'll fit a probability distribution to our data to characterize the data and determine if the two samples have different failure rates as a function of time.

5.7 Perform Weibull Analysis on Survival Data

Survival data commonly follows a Weibull distribution. We'll check that our data follows a Weibull distribution and use the fitted distribution to estimate survival rates for our two configurations. The Statistics Toolbox has a graphical tool (dfittool) that provides a central access point for fitting distribution to data and performing related calculations from the fitted distributions. We'll use this tool to perform our Weibull Analysis on Controller 1, generate M-files to capture our analysis, and apply the analysis to Controller 2.

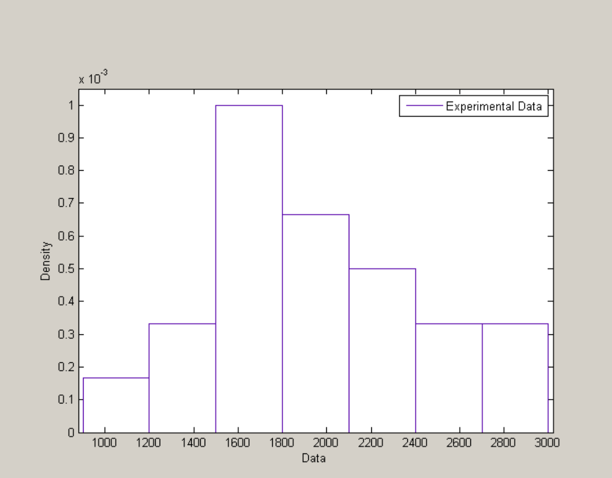


Fig.5.17

5.8 Compare Survival Times for Each Controller

You have seen the analysis performed for Controller 1. We'll now use the M-file functions generated from our work in dfittool on configuration 2 and compare the results to configuration 1.

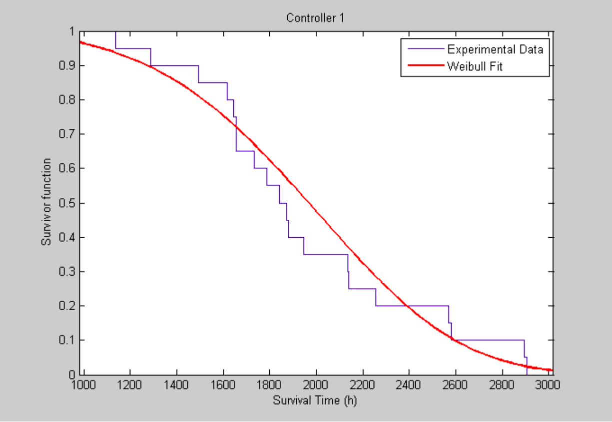


Fig.5.18

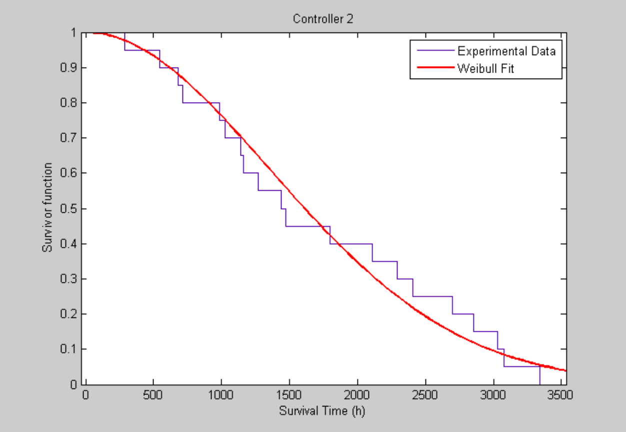


Fig.5.19

The Survivor Function Plots show the fraction of the population that are likely to fail over time. Controller 1 has >95% survival rate at 1,000 hours. This meets our goal. Contorller 2, on the other hand, has a survival rate of around 80% at 1,000 hours. This does not meet our goal. Therefore, Controller 1 is the selected configuration for our application.

5.9 Summary

We have seen that the two controller configurations testted significantly reduce the amount of displacement and acceleration a passenger is exposed to. Controller 1 meets our reliability criteria as well as had the best overall performance. Controller 2, while cheaper, does not meet our reliability requirement of >90% for >1,000 hours. Thus, controller 1 is the configuration selected for further development.

6.0 Conclusion & Future Scope

6.1 conclusion

The magnitude and phase of STH Transmissibility, DPM impedance, apparent mass(AP) are calculated. From the simulation results the following points can be drawn:

1. Simulation of biodynamic model is carried in MATLAB which shows close match with experimental results from literature.
2. It is found that the response of bio-dynamics model is higher in the frequency range of 3.5 to 5.5 Hz. This shows that human body is more sensitive to vibration in this range of frequency. So this range should be avoided while designing suspension system of motorcycle.
3. The maximum DPM value is 2.44*103 N-s/m at 6.77 Hz.
4. It is observed that value of AP is maximum (83.2 kg) at 3.24 Hz.
5. The response of viscera is found to be higher than head and torso in the frequency range approximately 3.0 to 7.0 Hz.
6. Head has more phase delay relative to the upper and lower torso.
7. STH response is maximum at natural frequency of vehicle model suspension which is 4Hz. It reduces gradually at lower natural frequencies of suspension.

6.2 Future Scope

The main purpose of the project is to stimulate the vibrations on the body and compute the technical data. By using the ANSYS software we will be getting the technical data which will help us for getting the general view on how the vibrations are working & therefore to minimize the vibration energy on the body of the vehicle.

As the Ansys software is for the stimulating the interactions of disciplines of physics, structural, vibration, fluid dynamics, heat transfer and electromagnetic.

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