Analysis of The Vibration Transmissibility Of Automobile Seat Subject To Vertical Excitations

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***Abstract*—Entire body vibration causes a multifaceted sharing out of vibration within the body and disagreeable feelings giving rise to discomfort or exasperation result in impaired performance and health menace. The current study proposed a 4-DOF analytic biomechanical model of the human body in a sitting posture without backrest in vertical vibration direction to investigate the biodynamic responses of different masses & stiffness and Analysis by using Response Surface Method. Response surface methodology (RSM) is a collection of mathematical and statistical technique useful for analysing problems in which several independent variables influence a dependent variable or response and the goal is to optimize the response. The experimental set up will be design to get the entire speed range with the mass damper system. The mass damper system model will be formulated for the sitting posture like Auto Rickshaw human sitting posture. The biodynamic response characteristics of seated human subjects have been extensively reported in terms of apparent mass and driving-point mechanical impedance while seat-to-head vibration transmissibility has been widely used to characterize response behaviour of the seated subjects exposed to vibration. This Work helps to improve sitting comfort of commercial vehicle at various speed ranges and also improves Human work capability.**

Keywords— Biodynamic Responses, Analytic Seated Human Body Model (4-Dof), Response Surface Method, Optimization.

I. INTRODUCTION

Human body vibration is a phenomenon affecting millions of worker in the world surrounded by these are light and heavy equipment operators, m/c tool operator and truck driver. Many harmful side effects of the vibration can be both physiological and neurological which in many cases lead to permanent injury. High speed vehicles frequently convey dynamic forces to their inhabitant. Depending upon the intensity and period of such disturbances, serious damage of operator or passenger malfunctioning may occur. These problems have cause to extensive research directed towards defining and understanding the biodynamic response of the human body. Recently there has been increased fascination in the dynamics of the human body. Other attempts such as health and medical studies and even athletic interests have also created a desire for comprehensive human biodynamic analysis.

The vehicle driving comfort has become one of the important factors of vehicle quality and receives increasing attention. Since the description to vibrations may cause adverse effects on the human health, the comfort performance of the final product must be carefully evaluated and optimized in the virtual engineering process, in order to assurance the comfort performance of the final product that strikes the road. The two wheeler and three wheelers like Auto Rickshaw riders are subjected to extreme vibrations due to the vibrations of its engine, irregular structural design of the vehicle and bad state of road. These vibrations are most hazardous to the health, if it run over the permissible limit and may cause the illness of the spine, musculoskeletal manifestation in the lower back as well as the neck and upper limbs.

The Taguchi approach and Response Surface Method will be used for the analysis and modelling of the various response obtain from the human body.

II. PROBLEM STATEMENT:

To investigate the biodynamic response behaviors of seated human body subject to whole-body vibration and analytical techniques will be proposed in this study. The numerical models proposed in this study utilized response surface method (RSM) using the experimental data. Biodynamic response behaviors and then can predict the behaviors for different data of the human body without the need to go through the analytical solution.

III. LITERATURE REVIEW:

Whole-body vibration experiments have been extensively performed for a wide range of applications like in driving an automobile, sitting in an erect position, etc. In the past years, a lot of work has been done to investigate and analyze the whole body vibrations in standing posture. A review of the literature is presented here.

3.1 Wael Abbas1, Ossama B. Abouelatta, Magdi El-Azab And Mamdouh Elsaidy[1]

This paper has performed measurements for seated subjects with feet supported and hands held in a driving position. Variations in the seated posture, backrest angle, and nature and amplitude of the vibration excitation are introduced within a prescribed range of likely conditions to illustrate their influence on the driving-point mechanical impedance of seated vehicle drivers. Within the 0.75-10 Hz frequency range and for excitation amplitudes maintained below 4m/s2, a four-degree-of-freedom linear driver model is proposed for which the parameters are estimated to satisfy both the measured driving-point mechanical impedance and the seat-to-head transmissibility characteristics defined from a synthesis of published data for subjects seated erect without backrest support.

3.2 S. Rakheja1, R.G. Dong, S. Patra, P.E. Boileau, P. Marcotte And C. Warren[2]

The reported data on biodynamic responses of the seated and standing human body exposed to whole-body vibration along different directions and the associated experimental conditions are systematically reviewed in an attempt to identify datasets that are likely to represent comparable and practical postural and exposure characteristics. Syntheses of datasets, selected on the basis of a set of criterion, are performed to identify the most probable ranges of biodynamic responses of the human body to whole-body vibration. These include the driving-point biodynamic responses of the body seated with and without a back support while exposed to foreaft, lateral and vertical vibration and those of the standing body to vertical vibration, and seat-to-head vibration transmissibility of the seated body. The proposed ranges are expected to serve as reasonable target functions in various applications involving coupled human-system dynamics in the design process, and potentially for developing better frequency-weightings for exposure assessments.

3.3 Zengkang Gan, Andrew J. Hillis And Jocelyn Darling[3]

In this paper, a lumped-parameter biodynamic model of a seated human body (SHB) exposed to low frequency wholebody vibration in both vertical and fore-and-aft directions is developed. The model is based on all three types of biodynamic functions: seat to- 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 behavior 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.

3.4 Cho-Chung Liang And Chi-Feng Chiang[4]

This paper has studied the lumped-parameter models for seated human subjects without backrest support under vertical vibration excitation has been carried out. As part of the study, all models have been analyzed systematically, and validated by the synthesis of various experimental data from published literature. Based on the analytical study and experimental validation, the four degree-of-freedom (DOF) model is developed. A simple model that captures the essential dynamics of a seated human exposed to whole body vibration. Investigated in describing the motions of a seated body, two multi body models representative of the automotive postures, one with and the other without a backrest support. Both models were modified to suitably represent the different automotive postures with and without backrest supports, and validated by various experimental data. On the basis of the analytical study and the experimental validation, the fourteen-degrees-of-freedom model proposed in this research was found to be best fitted to the test results.

3.5 Supriya Sambhaji More, R.V.Bhortake[5]

This paper explains the analysis of vibrations impact on various parts of human body while performing operation on lathe machine in standing posture. Multi degree freedom vibratory lumped parameter model is developed to investigate biodynamic response of different masses & stiffness. The effects of mechanical vibrations on the human body can be divided into three main groups a) Effects of very low frequency vibrations (1-2 Hz) that cause kinetosis, known also as motion sickness, car or sea sickness. Symptoms include malaise, asthenia, dizziness, pallor, cold sweat and nausea. b) Effects of low frequency vibrations (2-20 Hz) caused by surfaces, plants and machinery.

IV. EXPERIMENTATION:

4.1 Experimental Setup:

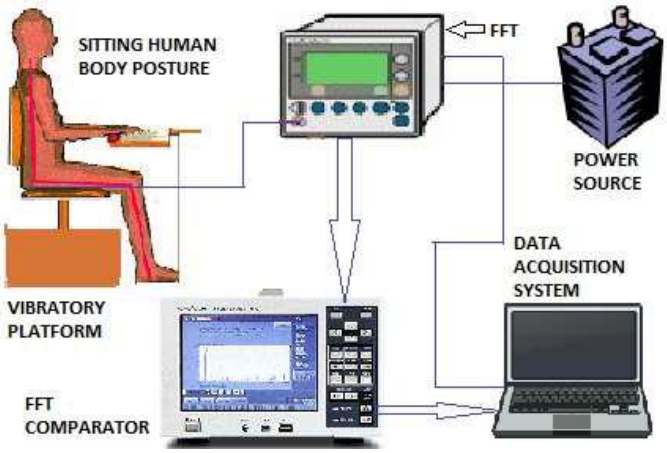

Fig.1. Experimental Setup()

4.2 Important Identifying Parameters**:**

From the literature review and previous work done among many independently controllable parameters affecting biodynamic response of seated human model ,the parameters viz Cushion(A), Age(B), Weight(C) and three Levels Low, Medium, High were selected as primary parameters for the

study. Different combinations of parameters were used to carry out the trial runs. This was carried out by varying one of the factors while keeping the rest of them at constant values.

Table 1: Parameters Level Selected for the Experimentation

Parameters	Levels		
	Low(1)	Medium(2)	High(3)
Parameter A [Cushion]	3 cm	6 cm	8 cm
Parameter B [Age]	18-25	25-35	36-45
Parameter C [Weight]	Less	Medium	High

4.3 Conducting Experiment:

For conducting experiments three different speeds of vehicle, three different sizes of cushion i.e. 1,2,3 and three different persons of different age, height and weight were selected. Using FFT (Fast Fourier Transformer) analyser vibration reading were recorded and Frequencies were measured. By using these Frequencies the Transmissibility Ratio was calculated as follows.

V. RESULTS AND DISCUSSION:

5.1 Development of mathematical model:

5.1.1 Response surface methodology [1]:

Response surface methodology (RSM) is a collection of mathematical and statistical technique useful for analyzing problems in which several independent variables or response and the goal is to optimize the response. In many experimental conditions, it is possible to represent independent factors in quantitative form as given in Eq.(1).Then these factors can be thought of as having a functional relationship or response as follows:

$Y=\Phi(x1,\ x2,\ldots,xk)\pm e_r$…….…….. Eq.(1)

Between the response Y and $x1$, $x2$, …, x_k of k quantitative factors , the function Φ is called response surface or response function. The residual e_r measures the experimental errors. For a given set of independent variables, a characteristic surface is responded. When the mathematical form of Φ is not known, it can be approximate satisfactorily within the experimental region by polynomial. In the present investigation, RSM has been applied for developing the mathematical model in the form of multiple regression equations for quality characteristics of noise. In applying the response surface methodology, the independent variable was viewed as surface to which a mathematical model is fitted.

The second order polynomial (regression) equation used to represent the response surface Y is given by,

$Y = b0 + \Sigma bi\ xi + \Sigma bii\ xi + \Sigma bij\ xi\ x\ j + e_r$……..Eq.(2)

5.1.2 Response Surface Regression: TR versus CUSN(A), AGE(B), WT(C)

The following terms cannot be estimated, and were removed.

AGE(B)*WT(C)

The analysis was done using coded units.

Table 2: Estimated Regression Coefficients for TR

Term	Coef	SE Coef	T	P
Constant	-1.70322	0.34285	-4.968	0.000
CUSN(A)	2.48650	0.20489	12.136	0.000
AGE(B)	1.62483	0.26654	6.096	0.000
WT(C)	-0.53978	0.20011	-2.697	0.015
CUSN(A)*CUSN(A)	-0.29294	0.04402	-6.655	0.000
AGE(B)*AGE(B)	-0.17461	0.05083	-3.435	0.003
WT(C)*WT(C)	0.13411	0.05083	2.639	0.017
CUSN(A)*AGE(B)	-0.39589	0.05083	-7.789	0.000
CUSN(A)*WT(C)	-0.08333	0.05083	-1.640	0.118

S = 0.107822 PRESS = 0.470833

R-Sq = 96.33% R-Sq(pred) = 91.75% R-Sq(adj) = 94.70%

Table 2: Analysis of Variance for TR

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	8	5.49529	5.49529	0.68691	59.09	0.000
Linear	3	2.85819	2.46452	0.82151	70.66	0.000
Cusn (a)	1	2.28481	1.71213	1.71213	147.27	0.000
Age (b)	1	0.55933	0.43201	0.43201	37.16	0.000
Wt(c)	1	0.01406	0.08459	0.08459	7.28	0.015
Square	3	1.45712	0.76326	0.25442	21.88	0.000
Cusn(a)*cusn(a)	1	0.51490	0.51490	0.51490	44.29	0.000
Age(b)*age(b)	1	0.28066	0.13720	0.13720	11.80	0.003
Wt(c)*wt(c)	1	0.66157	0.08094	0.08094	6.96	0.017
Interaction	2	1.17998	1.17998	0.58999	50.75	0.000
Cusn(a)*age(b)	1	1.14873	0.70528	0.70528	60.67	0.000
Cusn(a)*wt(c)	1	0.03125	0.03125	0.03125	2.69	0.118
Residual error	18	0.20926	0.20926	0.01163		
Pure error	18	0.20926	0.20926	0.01163		
total	26	5.70455				

Table 3: Observation Table

Obs	Std Order	TR	Fit	SE Fit	Residual	Std Residual
1	1	0.867	1.056	0.062	-0.189	-2.14R
2	2	1.020	1.056	0.062	-0.036	-0.41
3	3	1.280	1.056	0.062	0.224	2.55R
4	4	1.490	1.540	0.062	-0.050	-0.57
5	5	1.560	1.540	0.062	0.020	0.23
6	6	1.570	1.540	0.062	0.030	0.34
7	7	1.880	1.943	0.062	-0.063	-0.72
8	8	1.930	1.943	0.062	-0.013	-0.15
9	9	2.020	1.943	0.062	0.077	0.87
10	10	1.850	1.880	0.062	-0.030	-0.34
11	11	1.840	1.880	0.062	-0.040	-0.45
12	12	1.950	1.880	0.062	0.070	0.80
13	13	2.020	2.153	0.062	-0.133	-0.51
14	14	2.120	2.153	0.062	-0.033	-0.38
15	15	2.320	2.153	0.062	0.167	1.89
16	16	2.390	2.453	0.062	-0.063	-0.72
17	17	2.450	2.453	0.062	-0.003	-0.04
18	18	2.520	2.453	0.062	0.067	0.76
19	19	2.120	2.220	0.062	-0.100	-1.14
20	20	2.320	2.220	0.062	0.100	1.14
21	21	2.220	2.220	0.062	-0.000	-0.00
22	22	2.560	2.640	0.062	-0.080	-0.91
23	23	2.620	2.640	0.062	-0.020	-0.23
24	24	2.740	2.640	0.062	0.100	1.14
25	25	1.850	1.817	0.062	0.033	0.38
26	26	1.740	1.817	0.062	-0.077	-0.87
27	27	1.860	1.817	0.062	0.043	0.49

R denotes an observation with a large standardized residual.

Table 4: Estimated Regression Coefficients for TR using data in uncoded units

Term	Coef
Constant	-12.0970
CUSN(A)	4.61672
AGE(B)	3.11506
WT(C)	-0.909556
CUSN(A)*CUSN(A)	-0.292944
AGE(B)*AGE(B)	-0.174611
WT(C)*WT(C)	0.134111

CUSN(A)*AGE(B)	-0.395889
CUSN(A)*WT(C)	-0.0833333

5.2 Optimizing parameters:

Surface Plot and Contour Plot:

Contour plots show distinctive circular shape indicative of possible independence of factors with response. A contour plot is produced to visually display the region of optimal factor settings [2]. For second order response surfaces, such a plot can be more complex than the simple series of parallel lines that can occur with first order models. Once the stationary point is found, it is usually necessary to characterize the

Contour Plots for TR:

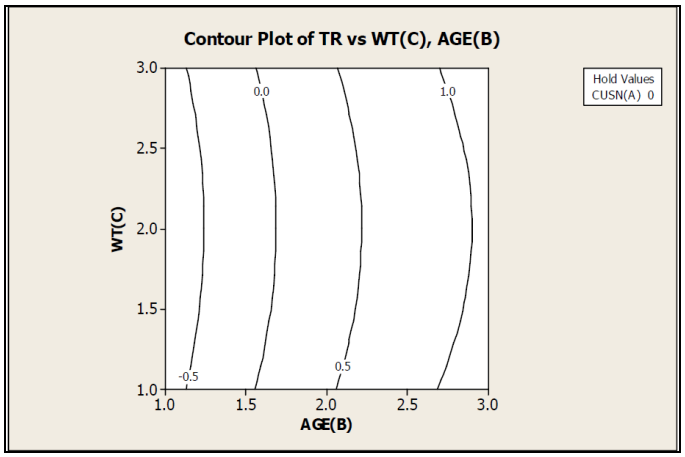

Fig.2 (a)

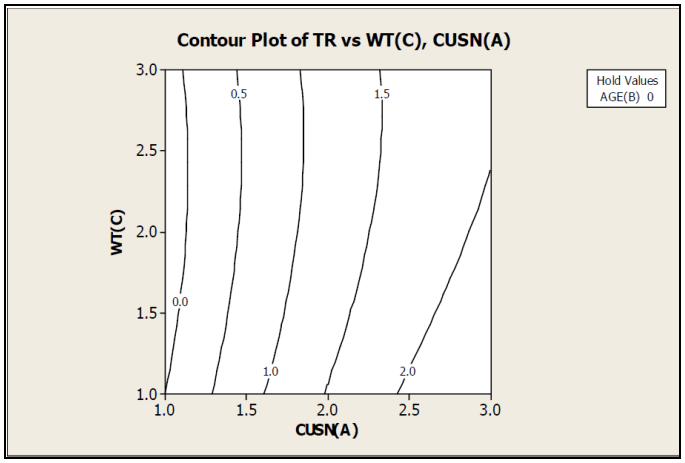

Fig.2 (b)

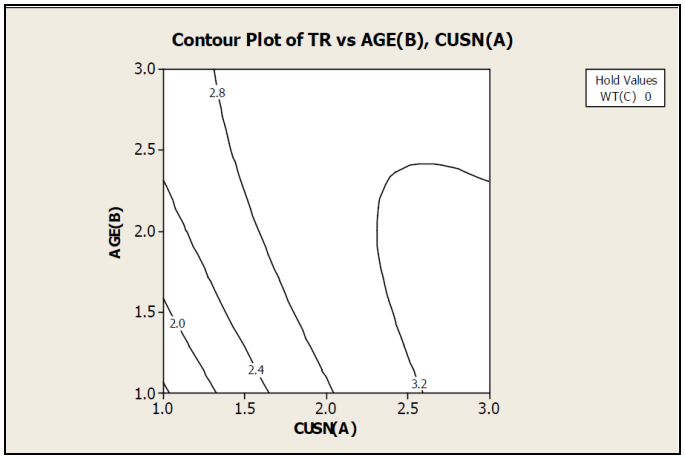

Fig.2 (c)

response surface in the immediate vicinity of the point by identifying whether the stationary point found is a maximum response or minimum response or a saddle point. To classify this, the most straightforward way is to examine through a contour plot. Contour plots play a very important role in the study of the response surface. By generating contour plots using software for response surface analysis, the optimum is located with reasonable accuracy by characterizing the shape of the surface. If a contour patterning of circular shaped contours occurs, it tends to suggest independence of factor effects while elliptical contours as may indicate factor interactions. Response surfaces have been developed for both the models, taking two parameters in the middle level and two parameters in the *X* and *Y* axis and response in *Z* axis.

Fig.2 presents three and two dimensional response surface plots for the STHT response obtained from the regression model.

Surface plots for TR:

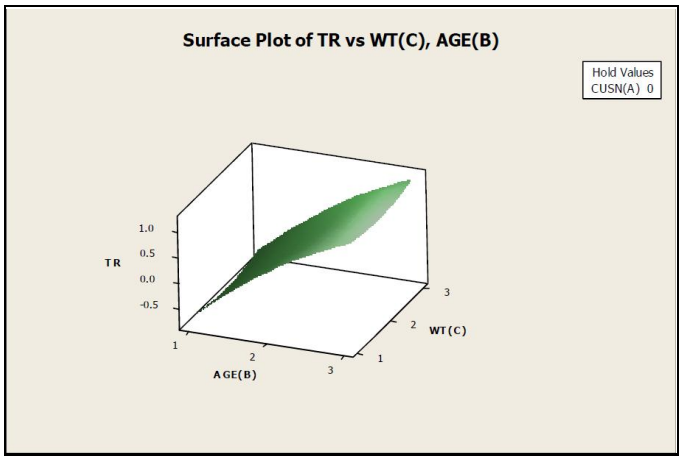

Fig.2 (d)

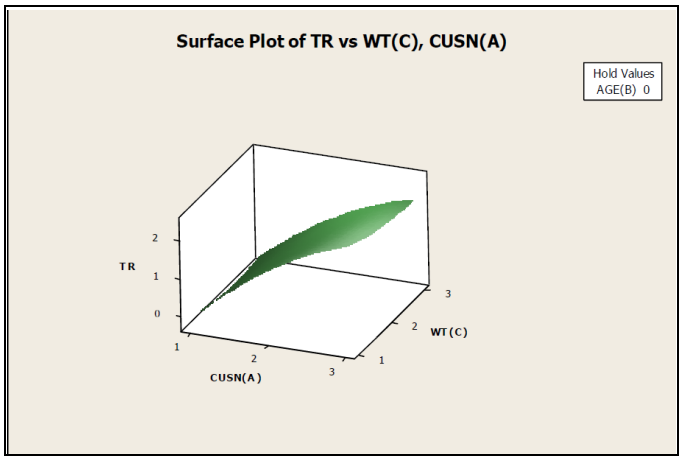

Fig.2 (e)

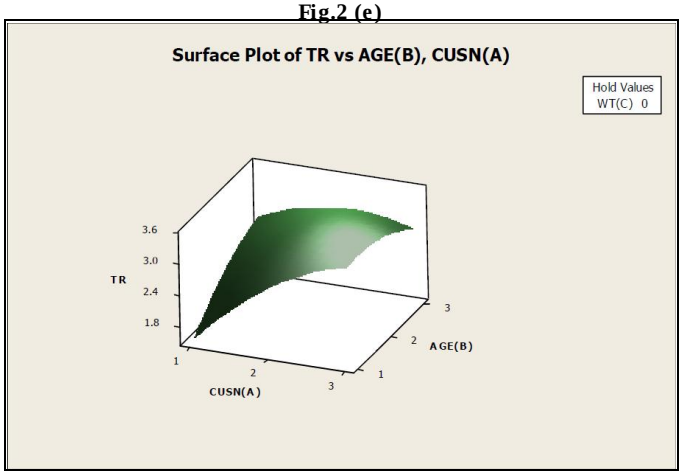

Fig.2 (f)

VI. CONCLUSION

Experiment and analytical studies conducted on the human body suggest that whole body vibration can cause spinal injury which results in low back pain. Most of the research reported in the literature on human body vibration has used sinusoidal motion to approximate the stimulus to the body. The human body is an immensely complex active multi body dynamic system, the properties of which vary with time. However the most important objective is to analyze and find procedures and method to minimize the effects of vibration on the human body based on such a model.

Based on the analytical investigation conducted in the course of the current research, it could be concluded that the human body's mass, pelvic stiffness, and pelvic damping coefficient give a remarkable change in biodynamic response behaviours of seated human body (direct proportional for human body's mass and pelvic stiffness coefficient and inverse proportional for pelvic damping coefficient.) Based on the results of implementing the RSM technique in this study, the following can be concluded:

1. The developed RSM models presented in this study are very successful in simulating the effect of human body's mass and stiffness on the biodynamic response behaviours under whole-body vibration.
2. The presented RSM models are very efficiently capable of predicting the response behaviours at different masses and stiffness rather than those used in the analytic solution.

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