Analytical Investigation and Numerical Prediction of Driving Point Mechanical Impedance for Driver Posture By Using ANN.

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Abstract

In vibration human body is unified and complex active dynamic system. Lumped parameters are offered used to capture and evaluate the human dynamic properties.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 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, for this kind of study we can use a neural network (ANN) which is a powerful data modeling tool that is able to capture and represent complex input/output relationship. The goal of ANN is to create a model that correctly maps the input to the output using historic data so that the model can be then used to produce the output when the desired output is unknown.

Keywords : DPMI, APMS, HTST, ANN, Lumped Parameter.

1 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

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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 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.

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 transmibility 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 stiffnes model were not provided but values were similar to experimental data obtained by vogt et al [4]. The model performance were compared with experimental data for acceleration ratio given by Goldman and von Girke et al [11]. 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 inThe 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 increase 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 to define percentile of dummy and initial position. The model in car occupant position has been mainly used to compute human vibrational 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 method the equation of transient response and power spectrum density were established ,after performing simulation to vehicle vibration of changeable driving show that psudo-excitation method is more convenient than traditional method and the smoothness computation problem of vehicle ,while psudo-excitaton 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 a spring stiffness and shock absorber damping values of bus suspension system ,needed to have acceptable oscillatory behavior. He analyses 3 important oscillatory parameters in frequency domain. This type of analysis allows to choice values of oscillatory parameters of bus suspension system depending on different excitation frequency values ,Similarly 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 having 0.5 m/s2and 1m/s2rms 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.

1.1 Basic Assumption for Experimentation

The biodynamic of seated human subjects exposed to vertical vibration has been widely assessed in terms of STHT, DPMI, and APMS. The first function refers to the transmission of motion through the body, while the other two relate the force and motion at the point of vibration input to the body. A variety of test data used to characterize these response functions has been established using widely varied test conditions. This has resulted in considerable discrepancies among the data. To avoid these discrepancies, a preliminary conclusion was reached that any attempt to define generalized values might not be appropriate unless it could be defined specifically for a particular application or within a limited and well defined range of situations Data sets satisfying the following requirements are selected for the synthesis of biodynamic characteristics of the seated human posture. A human subject is considered to be sitting erect without backrest support, irrespective of the hands position.

- Body masses will be limited within 49-94 kg.
- Feet are supported and vibrated.
- Analysis is constrained to the vertical direction.

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

2 Analytical Model and Calculation of Parameters

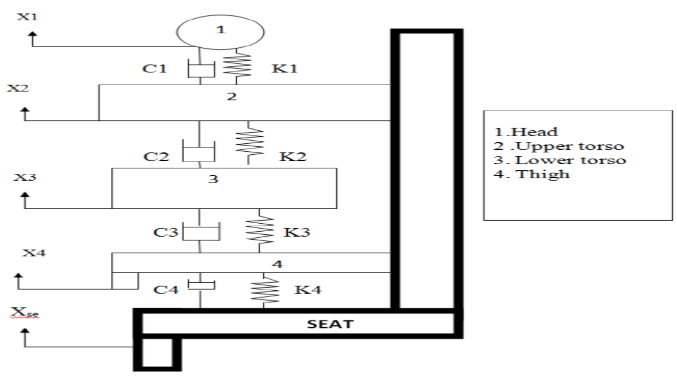

Figure 1: Seating Posture of Human Model

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. 1 consists of four mass segments interconnected 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, assuming 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).

2.1 Response Measure

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

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$$Z(j_w) = F(j_w)/V(j_w)$$

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

Table 1: Anthropometric data for driver

Sr.No.	Parameters	Notation	Driver 1	Driver 2	Driver 3
1	Standing Height	L1	167.09	167.23	169.11
2	Shoulder Height	L2	144.98	145.9	147.52
3	Armpit Height	L3	135.23	135.53	136.95
4	Waist Height	L4	107.23	107.86	109.14
5	Seated Height	L5	91.52	91.98	91.92
6	Head Height	L6	21.02	21.2	20.74
7	Head Breadth	L7	14.7	14.9	15.30
8	Head to Chin Height	L8	22.25	22.14	23.14
9	Neck Circumference	L9	37.85	37.9	38.05
10	Shoulder Breadth	L10	45.70	45.9	46.24
11	Chest Depth	L11	23.24	23.1	23.42
12	Chest Breadth	L12	32.59	32.5	32.68
13	Waist Depth	L13	21.39	21.09	21.67
14	Waist Breadth	L14	28.33	28.02	28.47
15	Buttock Depth	L15	22.87	22.98	23.37
16	Hip Breadth, Standing	L16	35.53	35.1	35.67
17	Shoulder to Elbow Length	L17	37.49	37.27	37.62
18	Forearm -Hand Length	L18	47.98	48.39	48.49
19	Biceps Circumference	L19	32.33	32.39	33.08
20	Elbow Circumference	L20	31.57	31.22	32.48
21	Forearm Circumference	L21	29.37	29.09	29.88
22	Wrist Circumference	L22	17.37	17.46	18.08
23	Knee Height,seated	L23	52.92	52.98	53.54
24	Thigh Circumference	L24	50.55	50.14	50.78
25	Upper Leg Circumference	L25	37.22	37.08	37.76
26	Knee Circumference	L26	36.34	36.14	36.54
27	Calf Circumference L27	33.27	33.13	33.72	
28	Ankle Circumference	L28	22.13	22.01	21.38
29	Ankle Height Outside	L29	6.48	6.53	6.98
30	Foot Breadth	L30	10.15	10.3	9.89
31	Foot Length	L31	25.52	25.6	25.69
	Weight		**63.5**	**70.5**	**88.5**

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$$\{DPMI(j_w)\} = |(c_4 + \frac{k_4}{j_w})(\frac{x_4(j_w)}{x_0(w)}) - (c_4 + \frac{k_4}{j_w})|$$

In a similar manner, the apparent mass response relates the driving force to the resulting acceleration response, and is given by table 1.
On the basis of anthropometric Biodynamic data , the proportion of total body weight estimated for different body segments is 7.5% for the head and neck, 40.2% for the chest and upper torso, 12.2% for the lower torso, and 18.2% for the thighs and upper legs. For a seated driver with mean body mass, maintaining an erect back not supported posture, 78% of the weight was found to be supported by the seat. The biomechanical parameters of the human model(Stiffness, Damping) are listed in following Table.

Table 2: Final Mass Calculation

Sr.No.	Segments	Notation	Proposition	Driver 1	Driver 2	Driver 3
1	Total Body Weight	M	——-	63.5	70.5	88.5
2	Head and Neck	m1	7.5% of m	4.7625	5.2875	6.6375
3	Chest and Upper Torso	m2	40.2%of m	25.527	28.341	35.577
4	Lower Torso	m3	12.2% of m	7.747	8.601	10.797
5	Thighs and Upper Legs	m4	18.2 % of m	11.557	12.831	16.107
6	Seat	m5	78 % of m	49.53	54.99	69.03

Table 3: Final Stiffness Calculation

S.N	Segments	Notation	Magnitude (N/m)
2	Head and Neck	k1	310000
3	Chest and Upper Torso	k2	183000
4	Lower Torso	k3	162800
5	Thighs and Upper Legs	k4	90000

Table 4: Final Damping Coefficient Calculation

S.N	Segments	Notation	Magnitude (N/m)
2	Head and Neck	c1	400
3	Chest and Upper Torso	c2	4750
4	Lower Torso	c3	4585
5	Thighs and Upper Legs	c4	2064

Table 5: Mass matrix for Driver 1

4.7625	0	0	0
0	25.525	0	0
0	0	7.747	0
0	0	0	11.557

Table 6: Mass matrix for Driver 2

5.2875	0	0	0
0	28.341	0	0
0	0	8.601	0
0	0	0	12.831

Table 7: Mass matrix for Driver 3

6.6375	0	0	0
0	35.577	0	0
0	0	10.797	0
0	0	0	16.107

Table 8: Stiffness matrix

-31000	310000	0	0
310000	-493000	183000	0
0	183000	-345800	162800
0	0	162800	-252800

Table 9: Damping Coefficient matrix

-400	400	0	0
400	-5150	4750	0
0	4750	-9335	4585
0	0	4585	-6649

2.2 Response Behaviors of the Driver Body

1. **Effect of Different Driver Bodys Mass**
   Three different driver1,2 and driver3 of body masses (63.5, 70.5 and 88.5 kg) are used to investigate the effect of mass on the response behaviors of human body (STHT,DPMI and APMS) as shown in the following table 10. From these figures, one can see that by increasing the human body mass, the biodynamic response characteristics of seated human body (STHT,

DPMI, and APMS) are increased.

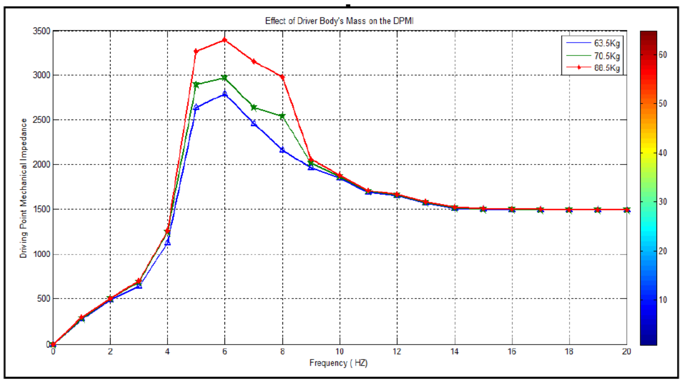


Figure 2: Effect of Driver Body's Mass on DPMI

2. **Effect of stiffness coefficient**
   Three different values of pelvic stiffness k4(Boileau value (B.V.), B.V. + 40%, and B.V. -40%) are used to investigate the effect of pelvic stiffness on the response behaviors of human body (STHT, DPMI and APMS) are shown in figure. From these figures, it is clear that by increasing the pelvic stiffness, the biodynamic response characteristics of seated human body (STHT, DPMI, and APMS) are increased.

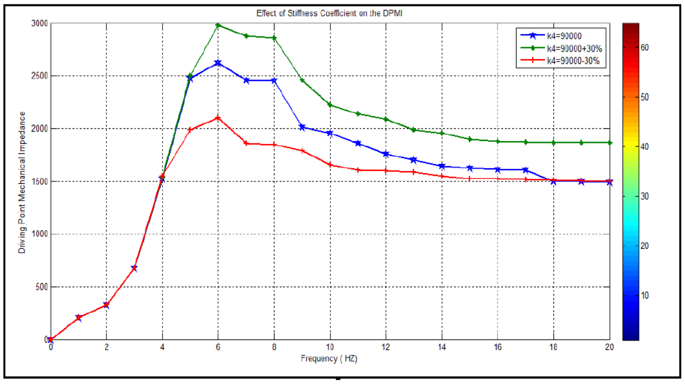


Figure 3: Effect of Stiffness on the DPMI

3. **Effect of damping coefficient**
   Three different values of pelvic damping coefficient C4 , +30%, and 30%) are used to investigate

the effect of pelvic damping coefficient on the response behaviors of human body (STHT, DPMI and APMS) as shown in figure. From these figures, it is clear that by increasing pelvic damping coefficient, the biodynamic response characteristics of seated human body (STHT, DPMI, and APMS) are decreased.

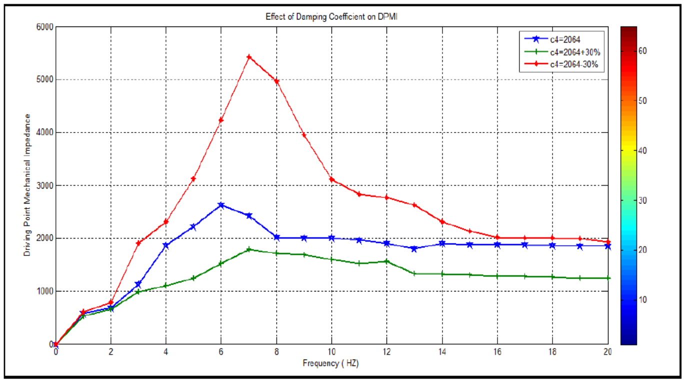


Figure 4: Effect of Damping Coefficient on DPMI

The different parameters like DPMI related to human body vibration at different values of frequencies are as follows,

freq.(HZ)	Driver 1	Driver2	Driver3
0	0	0	0
1	271.123	278.256	289.369
2	489.325	498.987	502.546
3	635.895	689.215	697.165
4	1123.548	1245.698	1259.638
5	2632.587	2896.654	3269.325
6	2789.638	2968.789	3389.125
7	2456.658	2636.897	3156.897
8	2158.697	2536.789	2978.124
9	1958.236	2012.698	2056.125
10	1852.697	1864.356	1879.356
11	1685.168	1702.637	1712.364
12	1650.136	1656.782	1666.127
13	1568.125	1578.236	1583.687

14	1506.367	1514.231	1523.456
15	1498.364	1503.487	1512.364
16	1493.256	1498.236	1503.569
17	1492.365	1496.236	1498.235
18	1492.362	1495.236	1497.234
19	1492.362	1495.236	1497.234
20	1492.362	1495.236	1497.234

Table 10: Effect of Mass on Different ratio DPMI

freq.(HZ)	K4	K4+30%	K4-30%
0	0	0	0
1	205.23	205.12	205.13
2	325.24	325.36	325.58
3	678.25	678.69	678.59
4	1523.58	1532.25	1545.26
5	2475.26	2502.36	1988.25
6	2623.25	2978.25	2102.53
7	2456.23	2875.23	1856.24
8	2448.36	2854.24	1845.26
9	2012.45	2453.45	1789.64
10	1956.24	2223.56	1658.23
11	1856.68	2136.36	1602.58
12	1756.68	2085.36	1598.63
13	1698.67	1987.65	1586.56
14	1645.65	1956.32	1546.21
15	1623.85	1896.34	1524.96
16	1612.58	1875.68	1521.63
17	1602.23	1872.69	1516.98
18	1498.63	1867.25	1512.64
19	1496.54	1864.24	1502.23
20	1492.65	1862.58	1498.63

Table 11: Effect of Stiffness of Different ratio K4 + 30% DPMI

freq.(HZ)	C4	C4+30%	C4-30%
0	0	0	0
1	576.23	523.85	602.35

2	678.69	656.23	786.53
3	1123.25	986.56	1896.23
4	1856.69	1102.35	2312.25
5	2223.25	1245.25	3123.25
6	2623.15	1523.54	4223.65
7	2423.25	1789.35	5423.36
8	2012.23	1708.25	4958.65
9	1998.23	1678.25	3945.63
10	1997.25	1596.32	3102.25
11	1958.65	1523.25	2825.69
12	1897.26	1555.25	2759.64
13	1798.58	1325.21	2623.15
14	1898.63	1312.12	2312.98
15	1875.32	1298.25	2123.56
16	1874.25	1275.25	2015.69
17	1872.21	1271.36	2002.68
18	1856.25	1269.25	1998.45
19	1854.36	1235.69	1987.25
20	1853.25	1233.57	1925.26

Table 12: Effect of Damping Coefficient of Different ratio C4 +-30% DPMI

3 Simulation By ANN

What is ANN?
A neural network is a powerful data modeling tool that is able to capture and represent complex input/output relationships .In the broader sense, a neural network is a collection of mathematical models that emulate some of the observed properties of biological nervous systems and draw on the analogies of adaptive biological learning. It is composed of a large number of highly interconnected processing elements that are analogous to neurons and are tied together with weighted connections that are analogous to synapses. To be more clear, let us study the model of a neural network with the help of figure.1. The most common neural network model is the multilayer perceptron (MLP). It is composed of hierarchical layers of neurons arranged so that information flows from the input layer to the output layer of the network. The goal of this type of network is to create a model that correctly maps the input to the output using historical data so that the model can then be used to produce the output when the desired output is unknown.

To develop a neural network model to simulate the effect of mass and stiffness on the biodynamic response behaviours of seated driver body, first input and output variables have to be determined. Input variables are chosen according to the nature of the problem and the type of data that would

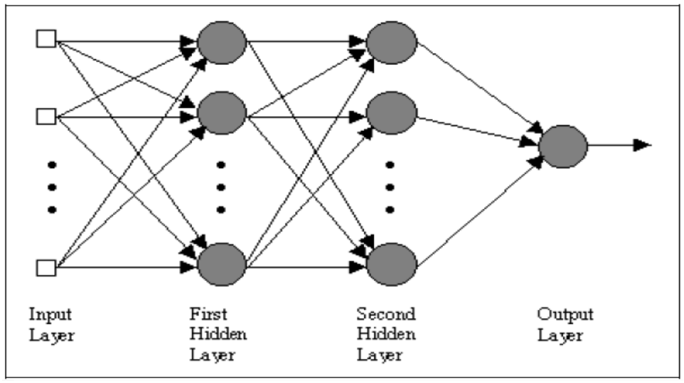


Figure 5: Graphical representation of MLP

be collected. To clearly specify the key input variables for each neural network simulation group and their associated outputs, Tables 10 and 11 are designed to summarize all neural network key input and output variables for the first and second simulation groups respectively. It can be noticed from Tables 1 and 2 that every simulation group consists of three simulation cases (three neural network models) to study the effect of mass and stiffness on the seat-to-head transmissibility (STHT), driving point mechanical impedance (DPMI) and apparent mass (APMS).

Numerical Simulation Cases
To fully investigate numerically the biodynamic response behaviors of seated drivers body subject to whole body vibration, several simulation cases are considered in this study. These simulation cases can be divided into two groups to simulate the response behaviors due to changing of driver bodys mass and stiffness respectively. From the analytic investigation, it is clear that the effect of damping coefficient is opposite to the effect of stiffness coefficient on the response behaviors of the human body. So in the numerical analysis, the effect of stiffness coefficient will be studied only in addition with the effect of human bodys mass.

3.1 Neural Network Design

To develop a neural network model to simulate the effect of mass and stiffness on the biodynamic response behaviors of seated human body, first input and output variables have to be determined. Input variables are chosen according to the nature of the problem and the type of data that would be collected. To clearly specify the key input variables for each neural network simulation group and their associated outputs, Tables 3 and 4 are designed to summarize all neural network key input and output variables for the first and second simulation groups respectively. It can be noticed from following Tables that every simulation group consists of three simulation cases (three neural network models) to study the effect of mass and stiffness on the seat-to-head transmissibility (STHT), driving point mechanical impedance (DPMI) and apparent mass (APMS).

The parameters of the various network models developed in the current study for the different simulation models are presented in table. These parameters can be described with their tasks as follows:

- Learning Rate (LR): determines the magnitude of the correction term applied to adjust each neurons weights during training process = 1 in the current study.
- Momentum (M): determines the life time of a correction term as the training process takes place =0.9 in the current study.
- Training Tolerance (TRT): defines the percentage error allowed in comparing the neural network output to the target value to be scored as Right during the training process = 0.001 in the current study.
- Testing Tolerance (TST): it is similar to Training Tolerance, but it is applied to the neural network outputs and the target values only for the test data =0.003 in the current study.
- Input Noise (IN): provides a slight random variation to each input value for every raining epoch = 0 in the current study.
- Function Gain (FG): allows a change in the scaling or width of the selected function = 1 in the current study.
- Scaling Margin (SM): adds additional headroom, as a percentage of range, to the scaling computations used by Neuralist Software, Shin (1994), in preparing data for the neural network or interpreting data from the neural network = 0.1 in the current study.
- Training Epochs: number of trails to achieve the present accuracy.

Table 13: Case I : key input and output variables for the First Group to find out the effect of Driver Bodys Mass

Simulation case	Input Variables					Output
DPMI	Frequency	M1	M2	M3	M4	DPMI

Table 14: Case II : key input and output variables for the First Group to find out the effect of Stiffness Coefficient

Simulation case	Input Variables		Output
DPMI	Frequency	k4	DPMI

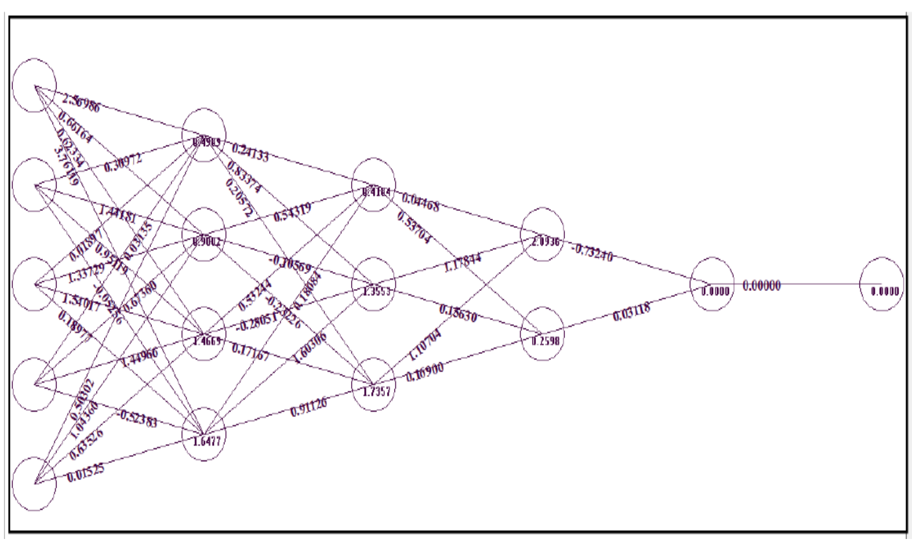
Table 15: Details of ANN Model

Simulation Group		No of Layers	Number of Neurons in Each Layer				
			I/p Layers	2 Hidden	3 Hidden	4 layer	O/p Layer
Ist Group	DPMI	5	5	4	3	2	1
			5	4	3	2	1
			5	4	3	2	1
IInd Group	DPMI	4	2	3	2	-	1
			2	3	2	-	1
			2	3	2	-	1

3.2 Results for Case I,II

Group I ANN Model (Mass Effect)

Group I : DPMI Networks



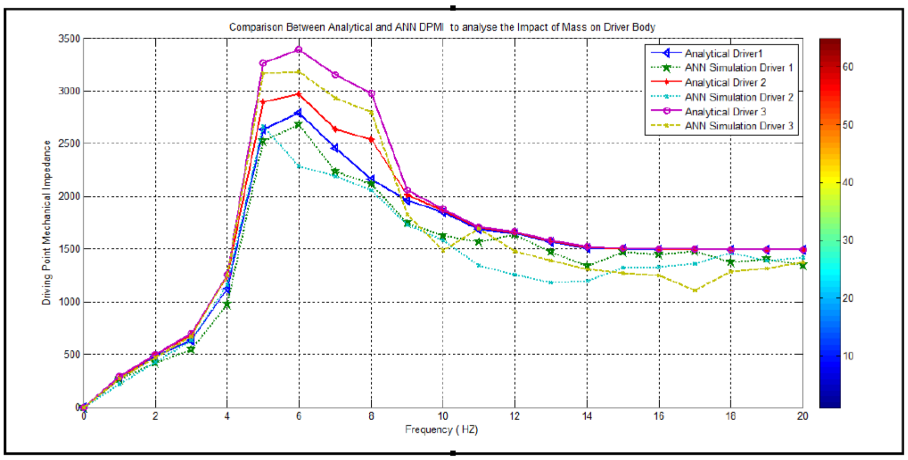
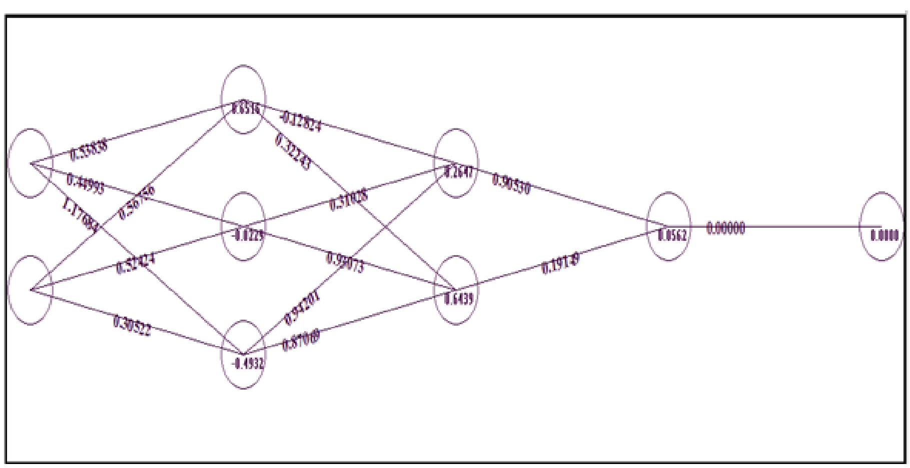


Figure 6: comparison between Analytical and ANN DPMI to analyze the impact of Mass on Driver body

Group II ANN Model (Stiffness Coefficient)



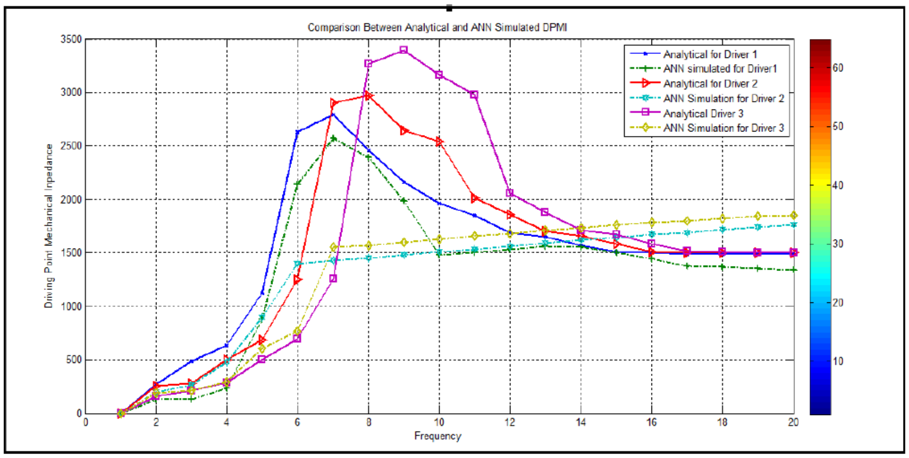


Figure 7: Comparison between Analytical and ANN simulated DPMI

Exp No	DPMI	DPMIANN
1	0	0
2	271	129
3	489	131
4	636	233
5	1120	879
6	2630	2136
7	2790	2569
8	2460	2389
9	2160	1986
10	1960	1480
11	1850	1500
12	1690	1530
13	1650	1560
14	1570	1555
15	1510	1498
16	1500	1440
17	1490	1378
18	1490	1365
19	1490	1355
20	1490	1342

Table 16: Operator 1

Exp No	DPMI	DPMIANN
21	149	175
22	256	198
23	278	263
24	499	477
25	689	896
26	1250	1400
27	2900	1430
28	2970	1450
29	2640	1480
30	2540	1510
31	2010	1530
32	1860	1560
33	1700	1590
34	1660	1620
35	1580	1640
36	1510	1670
37	1500	1690
38	1500	1720
39	1500	1740
40	1500	1760

Table 17: Operator 2

Exp No	DPMI	DPMIANN
41	156	178
42	163	189
43	212	212
44	289	296
45	503	606
46	697	765
47	1260	1550
48	3270	1570
49	3390	1600
50	3160	1630
51	2980	1660
52	2060	1680
53	1880	1710

54	1710	1730
55	1670	1760
56	1580	1780
57	1520	1800
58	1510	1820
59	1500	1840
60	1500	1850

Table 18: Operator 3

4 ANN Result and Discussion

Numeric Results and Discussions
Numerical results using ANN technique will be presented in this section for the two groups (six models) to show the simulation and prediction powers of ANN technique for the effect of driver bodys mass and stiffness coefficient on the biodynamic response behaviors (STHT, DPMI and APMS) subject to whole-body vibration.

4.1 Effect of human bodys mass

Three ANN models are developed to simulate and predict the effect of driver bodys mass on the biodynamic response behaviors (STHT, DPMI and APMS). Figures show the ANN results and analytical ones for different human bodys masses. From ANN figures, it is very clear that ANN understands and simulates very well the biodynamic response behaviors. After that the developed ANN models used very successfully and efficiently to predict the response behaviors for different masses rather than those used in the analytic solution as shown in the predicted figures of ANN results.

4.2 Effect of stiffness coefficient

Another three ANN models are developed in this sub-section to simulate and predict the effect of stiffness coefficient (k4) on the biodynamic response behaviors (STHT, DPMI and APMS). Figures show the ANN results and analytical ones for different values of k4. From ANN training figures, it is very clear that ANN understands and simulates very well the biodynamic response behaviors. After that the developed ANN models used very successfully and efficiently to predict the response behaviors for different values of k4 rather than those used in the analytic solution as shown in the predicted figures of ANN results.

5 Conclusions

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

1. The developed ANN models presented in this study are very successful in simulating the effect of human bodys mass and stiffness on the biodynamic response behaviors under whole-body vibration.

2. The presented ANN models are very efficiently capable of predicting the response behaviors at different masses and stiffness rather than those used in the analytic solution.

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