STUDY OF VIBRATION AND ITS EFFECTS ON HEALTH OF A TWO WHEELER RIDER

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Abstract

Majority of Indian population depends on a two wheeler for their transportation due to economic reasons. Because of improper design of vehicle and bad road conditions, people in the age group of 30 to 45 years have pains developed in their body. The percentages of people having musculoskeletal pain problems are found to be 13.33%. Hence an attempt has been made to analyze and obtain the idealized operating conditions of the human body. The analysis has shown that for the given vehicle and human body, the idealized operating speed for HERO HONDA SPLENDOR vehicle on the terrain of specified amplitude at given input is found to be 49.66 km/hr.

Index Terms: two wheeler, HERO HONDA SPLENDOR, musculoskeletal, amplitude

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1. INTRODUCTION

The two wheeler riders are subjected to extreme vibrations due to the vibrations of its engine, improper structural design of the two wheeler and bad road conditions. These vibrations are most hazardous to the health, if it exceeds the permissible limit and may cause the illness of the spine, musculoskeletal symptom in the lower back as well as the neck and upper limbs. Experimental studies on the transmission and tolerance of vertical vibrations which are beyond the permissible limit according to the literatures confirms that, vibrations certainly affect the health of the two wheeler rider. Therefore it is necessary to evaluate the influence of vibration to the human body and to make up appropriate guidelines for the two wheeler design and selection parts. The intensity of these harmful vibrations is reduced by providing a standard type of seat, front and rear suspension. In this work, the coupled human body and two wheeler is modelled as a lumped parameter system. The composite model is analysed by a computer program (MAT lab) for vertical vibrations responses of the body parts to vertical vibrations inputs (sinusoidal) applied to wheels.

1.1 Hand Arm Vibration and Its Effects

Hand arm vibration (HAV) is vibration transmitted from handheld equipment such as jack hammers and steering wheel and handle bar into the hands and arms of operators. It leads to vibration induced white finger (VWF). If detected early, this disease is curable. If not, it can cause permanent disability in the use of the hands [1]. Steering wheel vibration levels as high as 1 m/s2 have been reported in one study. HAV at this

level may present a slight risk of injury considering the long exposure durations of driving. It was also observed that the rates of finger numbness, finger stiffness, and shoulder pain and shoulder stiffness were significantly higher among traffic motorcyclists as compared with the control group [2].

1.2 Whole Body Vibration and Its Effects

Whole body vibration (WBV) occurs when workers sit or stand on vibrating seats or foot pedals. Prolonged exposure to high levels of WBV causes motion sickness, fatigue and headaches. WBV is one of the strongest risk factors for low back disorders [3]. Vibrations with less than 0.315m/s2 are found to be comfortable between 0.315m/s2 and 2.5m/s2 are found to be uncomfortable greater than 2.5m/s2 are found to be extremely uncomfortable [4].

Typical whole-body vibration exposure levels of heavy vehicle drivers are in the range 0.4 to 2.0 m/s2. Vibration is highest in the frequency range 2 to 4 Hz. For a seated person vibration in the range of 4 to 8 Hz cause the entire upper torso to resonate and should be reduced and avoided [3]. Health effects that associated with WBV and especially the driving environment are piles, high blood pressure, kidney disorders and impotence.

2. METHODOLOGY

The methodology of the study is briefly summarized as follows:

1. Modeling of human body,

2. Modeling of two wheeler,
3. Whole body system,
4. Mathematical formulation of the model adopted,
5. Analyzing.

2.1 Modeling of Human Body:

In this study, the model adopted is proposed by Patil and Palanichamy [6], popularly known as "Patil's 7 DOF model". Basically this model is modification of Muskian model (1974), which includes the damping and elasticity of the buttocks. It has 7 DOF & 7 lumped masses which are as follows.

- Head (M_1)
- Back (M_2)
- Torso (M_3)
- Thorax (M_4)
- Diaphragm (M_5)
- Abdomen (M_6)
- Pelvis (M_7)

The arms and legs are combined with the torso, pelvis respectively. These mass segments are interconnected by springs and dashpots representing the elastic and damping properties of the connective tissues between the segments. The selected values of the tissue springs and dashpots parameter are based on the studies of the characteristics of the specific subsystems by Muskian [7].

2.2 Modeling of Two Wheeler:

The model chosen for the study is HERO HONDA SPLENDOR. This is idealized by

- Seat (M_9)
- Handlebar (M_8)
- Chassis (M_{10})
- Front wheel (M_{11})
- Rear wheel (M_{12})

The engine and fuel tank are lumped together with chassis. It consists of standard type of seat, front, rear suspension system. These lumped mass segments are interconnected by spring and dashpots respectively. The tires are represented by linear vertical springs in parallel with velocity dependent dampers.
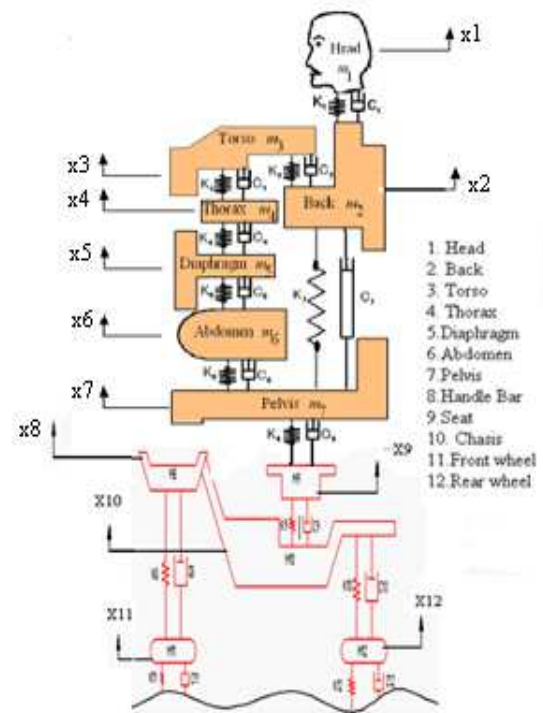

Fig-1: Coupled model (human body and two wheeler).

3. MATHEMATICAL FORMULATIONS

In deriving the dynamic model of the two wheeler and human for simulation and analysis the following simplifying assumptions were made, they are as follows:

- There exists only vertical motion of the vehicle.
- Both pitching and rolling motion are ignored in this study.
- The road profile was approximated to be of sinusoidal shape and is of 5cm amplitude.
- The spring characteristics were assumed to be linear.

The equation of motion for the coupled system is derived as follows

1. Head
$$M_1\ddot{x}_1 + C1\,(\dot{x}_1 - \dot{x}_2) + K_1(x_1 - x_2) = 0$$

2. Back
$$M2\ddot{x}2 + C1\,(\dot{x}2 - \dot{x}1) + C23\,(\dot{x}2 - \dot{x}3) + C2\,(\dot{x}2 - \dot{x}7) + K1(x2 - x1) + K23\,(x2 - x3) + K2\,(x2 - x7) = 0$$

3. Torso
$$M3\ddot{x}3 + C23\,(\dot{x}3 - \dot{x}2) + C3\,(\dot{x}3 - \dot{x}4) + K23\,(x3 - x2) + K3\,(x3 - x4) = 0$$

4. Thorax

$M_4 \ddot{x}_4 + C_4 (\dot{x}_4 - \dot{x}_5) + C_3 (\dot{x}_4 - \dot{x}_3) + K_4 (x_4 - x_5) + K_3 (x_4 - x_3) = 0$

5. Diaphragm

$M_5 \ddot{x}_5 + C_5 (\dot{x}_5 - \dot{x}_6) + C_4 (\dot{x}_5 - \dot{x}_4) + K_5 (x_5 - x_6) + K_4 (x_5 - x_4) = 0$

6. Abdomen

$M_6 \ddot{x}_6 + C_6 (\dot{x}_6 - \dot{x}_7) + C_5 (\dot{x}_6 - \dot{x}_5) + K_6 (x_6 - x_7) + K_5 (x_6 - x_5) = 0$

7. Pelvis

$M_7 \ddot{x}_7 + C_7 (\dot{x}_7 - \dot{x}_9) + C_6 (\dot{x}_7 - \dot{x}_6) + C_2 (\dot{x}_7 - \dot{x}_2) + K_7 (x_7 - x_9) + K_6 (x_7 - x_6) + K_2 (x_7 - x_2) = 0$

8. Seat

$M_9 \ddot{x}_9 + C_7 (\dot{x}_9 - \dot{x}_7) + C_9 (\dot{x}_9 - \dot{x}_{10}) + K_7 (x_9 - x_7) + K_9 (x_9 - x_{11}) = 0$

9. Handle bar

$M_8 \ddot{x}_8 + C_8 (\dot{x}_8 - \dot{x}_{11}) + K_8 (x_8 - x_{11}) = 0$

10. Chassis

$M_{10} \ddot{x}_{10} + C_9 (\dot{x}_{10} - \dot{x}_9) + C_{10} (\dot{x}_{10} - \dot{x}_{12}) + K_9 (x_{10} - x_9) + K_{10} (x_{10} - x_{12}) = 0$

11. Front wheel

$M_{11} \ddot{x}_{11} + C_8 (\dot{x}_{11} - \dot{x}_8) + C_{11} (\dot{x}_{11}) + K_8 (x_{11} - x_8) + K_{11} (x_{11}) = C_{11} A \omega \cos (\omega t) + K_{11} A \sin (\omega t)$

12. Rear wheel

$M_{12} \ddot{x}_{12} + C_{10} (\dot{x}_{12} - \dot{x}_{10}) + C_{12} (\dot{x}_{12}) + K_{10} (x_{12} - x_{10}) + K_{12} (x_{12}) = C_{12} A \omega \cos (\omega t) + K_{12} A \sin (\omega t)$

These equations of motions can be written in the matrix form as

$$[M] \{\ddot{X}\} + [C] \{\dot{X}\} + [K] \{X\} = \{F\} \qquad (1)$$

Where [M], [C] and [K] are 12x12 matrices The elements of mass, damping and stiffness matrices were obtained from equation of motion given above. All the elements of mass matrix are zero except diagonal elements. {F} is the 12x1 force column matrix. The entire elements force matrices are zero except 11th and 12th elements. The 11th and 12th elements sinusoidal forces are applied. These matrix forms are solved by matrix inversion method.

3.1 Determination of Response by Matrix Inversion Method

Matrix inverse method is a case, where the writing of the differential equation in the matrix form enables one to obtain the response of the system to forced vibration for damped multi degree of freedom system.

Assuming harmonic solution of the form

$$\{X\} = \{A\} \sin \omega t + \{B\} \cos \omega t \qquad (2)$$

Substituting equation (3.2) in (3.1) and equation the like terms equation becomes:

$$\{[K] - \omega 2 [M]\} \{A\} - \omega [C] \{B\} = \{F\} \qquad (3)$$

$$\omega [C] \{A\} + \{[K] - \omega 2 [M]\}\{B\} = \{0\} \qquad (4)$$

The above equation can be written as,

$$[A] \{X\} = \{F\}$$

Where $A = \{[K] - [M] \omega 2\} - \omega [C]$

Therefore displacement matrix,

$$\{X\} = \{F\} [A\text{-}1] \qquad (5)$$

This equation is a matrix equation of multi degree of freedom of the system. [A] can be obtained by matrix inversion method. The C program developed in this work calculates the [A] matrix for different frequency range (0.5 to 15Hz).

4. RESULTS AND DISCUSSION

The various results obtained for different frequency range (0.5 to 15 Hz) are listed below for the following sinusoidal input.
1. for front wheel:
f = C11 A ω Cos (ωt) + K11A Sin (ωt)

2. for rear wheel:
f = C12 A ω Cos (ωt) + K12A Sin (ωt)

Where,
A is the road profile was approximated to be of sinusoidal shape and is 0.05m   amplitude.
ω = 2πf, Frequency range (0.5 to 15 Hz).
C11 = C12 = Damping coefficient of the front and rear wheel.
K11 = K12 = Stiffness of the front and rear wheel.
t = Time period.

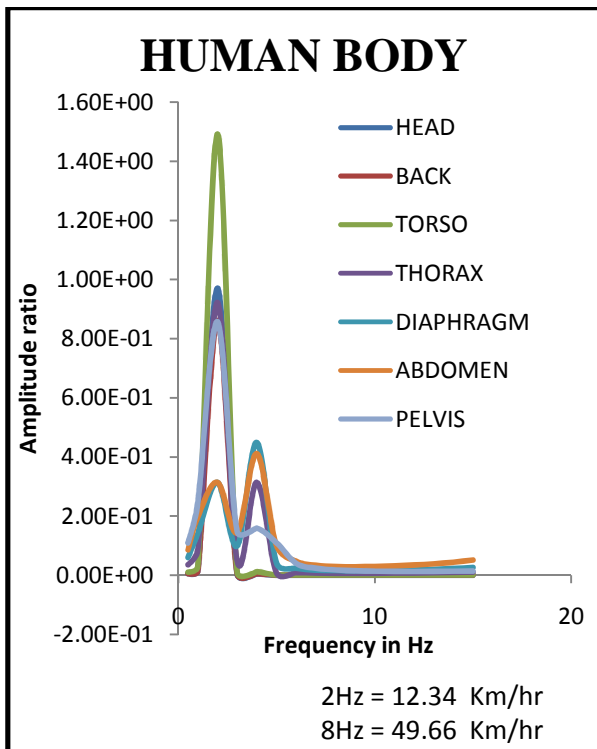Corresponding to each of the above, the frequency responses have been obtained.

Fig- 2: Frequency response of human body.

Table-1: Maximum amplitude ratio for different body segment.

Frequency in Hz	Human body Segment	Maximm response (amplitude ratio)	Vehicle speed km/hr.
2	Head	0.971	12.34
2	Back	0.861	12.34
2	Torso	1.49	12.34
2	Thorax	0.922	12.34
4	Diaphragm	0.449	24.80
4	Abdomen	0.411	24.80
2	Pelvis	0.858	12.34

CONCLUSIONS

Vibration is a physical disturbance that occurs in automobiles. The nature of vibration present in a vehicle depends upon the dynamic characteristics of the two wheeler and road surface characters. Its effect on the human body depends mainly on the frequency, magnitude, direction of vibration, area of contact and duration of exposure. Exposure to human body will result in transmission of vibratory energy to the entire body and leads to localized effect. It affects comfort, normal functioning of body and health. Exposure to certain frequencies of vibration may have effects on specific segment of the body. From the results it is found that, for the given frequency of two wheeler and human body the ideal operating condition is 8 Hz i.e. speed of the two wheeler should be 49.66 km/hr.

REFERENCES

[1]. Bridger R S "Introduction to Ergonomics," McGraw-hill International editions, 1995, pp. 318-349.

[2]. S. M Mirbod et al. "Assessment of Hand-Arm Vibration exposure among Traffic police motorcyclists," International Archives of occupational and Environmental health Vol. 70, 1997, pp. 22-28.

[3]. J. C Chent, J.T Dennerlein, L.M Ryan, "Predictors of whole-body vibration levels among urban taxi drivers," Ergonomics, Vol. 46, 2003, pp-1075-1090.

[4]. N. J Mansfield, "Human response to vibration".

[5]. R. R. Coermann, "The mechanical impedance of the human body in sitting and standing position at low frequencies. Human Factors", October 1962, pp. 227–253.

[6]. Mothira K. Patil, M.S. Palanichamy, Dhanjo N. Ghista, "Minimization of Tractor-Occupant's Traumatic Vibrational Response by Means of the "Patil-Palanichamy-Ghista" (PPG) Tractor Seat Suspension," Studies in Environmental Science, Vol.13, 1981, pp.364-371.

[7]. Farid M. L. Amirouche, "Modeling of Human Reactions to Whole-Body Vibration," Journal of Biomechanical Engineering, Vol.3, 1987, pp. 210-217.

BIOGRAPHIES

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