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Determining and Optimization of Mass, Stiffness and Damping Coefficients of Tractor Seat by Quasi-Newton Method Using Coupled Human-Seat Model

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Abstract: Reduction of seat to head transmissibility function in seated human body during driving has been the subject of research for many years. Many mathematical models for seated human body during driving has proposed. In the present study a model with four degrees of freedom is considered to optimize seat to head transmissibility function under harmonic excitation with 50 mm amplitude in agricultural vehicles. Optimized coefficients of mass, stiffness and damping for seat were obtained by quasi-Newton optimization method. The theoretical results were compared with the experimental results reported by other researches. A significant reduction in transmitted acceleration and therefore transmitted force to human body and seat to head transmissibility function were concluded by the above method.
Key words: quasi-Newton optimization method, STH transmissibility function; Transmitted acceleration ,Seat vibration ; coupled human- seat Model

INTRODUCTION

Human body models have been used for the study of the effect of vertical vibration for many years, due to the simplicity of these analyses and ease of comparison of the results with the experimental results [1]. In these models human is simulated by some lump masses, springs and dashpots. Coermann (1962) by measuring the body impedance (DPM) in different cases proposed a model with one degree of freedom [2]. Later; a model with two degrees of freedom was proposed by Suggs et. al; [3]. Muksian and Nash with two different models resulted that the damping coefficient varies with different frequency simulation [4 &5]. A model with seven degrees of freedom was used for the study of the effect of vertical vibration of the tractor seat on the body [6 &7]. A model with eleven degrees of freedom was used by Qassem et. al; for sitting men and another model was used for women [8 and 9]. A model with four degrees of freedom for analysis of the effect of vertical and horizontal vibration of the car on the human body was used by Wan and Shimmels in 1995 [10]. Boileau et al.; (1998) also proposed a four degrees of freedom model for analysis of the effect of vertical vibration on the body [11]. The model proposed by Wan and Shimmels has a good adaptability with the experimental result and is selected for the analysis of the human body responses to the vibration

Modeling

In low frequencies, human body can be modeled by a linear concentrated model.

Figure 1 shows a degree freedom model by Wan and Schimmels (1995). This model preferred among other model by Liang and Chiang.

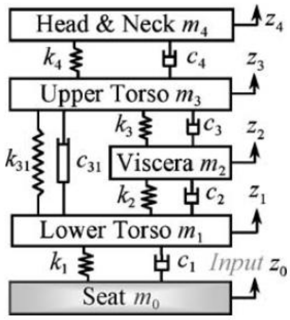

Figure 1. Four degree of freedom, Schimmels model

Table 1. Show the characteristic of the above model.

Mass (kg)		Damping (N.m/s)		Stiffness (N/m)	
m_1	36/00	c_1	2475/0	k_1	49340/0
m_2	5/50	c_2	330/0	k_2	20000/0
m_3	15/00	c_3	909/1	k_3	192000/0
		c_{31}	200/0	k_{31}	10000/0
m_4	4/17	c_4	250/0	k_4	134400/0

Dynamic functions

This biodynamic function which is called acceleration - displacement ratio, is defined as the ratio of output responses to input stimulation

$$TR = \frac{Z_i(i\omega)}{Z_0(\omega)} \tag{1}$$

Impedance DPM

This function is defined as motion force divided by velocity of stimulation point and is as follows:

$$IM = \left| \frac{(k_1 + i\omega c_1)[Z_0(\omega) - Z_1(i\omega)]}{i\omega Z_0(\omega)} \right| \tag{2}$$

Apparent Mass

This function is defined as a term of IM:

$$AP = \left| \frac{IM}{i\omega} \right| = \left| \frac{(k_1 + i\omega c_1)[Z_0(\omega) - Z_1(i\omega)]}{-\omega^2 Z_0(\omega)} \right| \tag{3}$$

Vertical vibration

For study of effect of vertical vibration on seated person , first the equations of motion of the concentrated model must be solved and then answers defined as biodynamic functions of STH , DPM , AP. As said before the evaluation of responses of human body to the vertical vibration is done in terms of these equations.

System of equation of motion

The equation of motion in terms of matrix functions is as follows:

$$[M]\{\ddot{z}\} + [C]\{\dot{z}\} + [K]\{z\} = \{f_z\} \tag{4}$$

In which [M], [C] and [K] are 4×4 mass, damping and stiffness matrices respectively and $\{z\}$ ، $\{\dot{z}\}$ and $\{\ddot{z}\}$ are displacement vectors, velocity and acceleration respectively.

6-the solution of equation of motions based on frequency method.

Since the lamped parameter model in this paper is a linear system, this model is analyzed by frequency domain method.

Since the boundary conditions are as follows:

$$(z_1)_0 = (z_2)_0 = (z_3)_0 = (z_4)_0 = (z_0)_0 = 0$$
$$(\dot{z}_1)_0 = (\dot{z}_2)_0 = (\dot{z}_3)_0 = (\dot{z}_4)_0 = (\dot{z}_0)_0 = 0$$
$$\dot{z}_i = \frac{dz_i}{dt} \tag{5}$$

The matrix equation of motion is

$$\{Z(s)\} = \{[K] - \omega^2 [M] - s\,[C]\}^{-1} \{F_z(s)\} \tag{6}$$

For $s = i\omega$ the equation of motion changed to the following forms:

$$\{Z(i\omega)\} = \{[K] - \omega^2 [M] - i\omega\,[C]\}^{-1} \{F_z(i\omega)\} \tag{7}$$

In which $\{F_z(i\omega)\}$ and $\{Z(i\omega)\}$ are Fourier complex transformed vector of $\{f_z\}$ and $\{z\}$ and w is the stimulus frequency.

It must be motioned that the vector $\{Z(i\omega)\}$ is the displacement response of five masses m1 to m5 and is stated as follow:

$$\{Z(i\omega)\}=\{Z_1(i\omega), Z_2(i\omega), Z_3(i\omega), Z_4(i\omega), Z_5(i\omega)\} \quad (8)$$

Optimization by Quassi Newton method

In this method , the function is approximated by a 2nd order equation. The with the use of Taylor series at $X = X_i$

$$f(X) = f(X^k) + \nabla^T f(X^k)\Delta X^k + \frac{1}{2}(\Delta X^k)^T H(X^k)\Delta X^k \quad (9)$$

In which $H(X) = \nabla^2 f(X)$

By a differentiation from $f(X)$ along X^k with respect to each component and solve it as a equation equal to zero, the optimum $f(X)$ can be obtained.

Therefore the direction of search in this method is

$$\Delta X^k = -[H(X^k)]^{-1}\nabla f(X^k) \quad (10)$$

The optimization algorithm is stopped when $f(X^{k+1}) < f(X^k)$

In this research by optimizing biodynamic function STH, acceleration, coefficients of mass, damping and stiffness was found as follows:

m_o=14 kg, c_o=125N.s/m, k_o=8130 N/m

RESULTS

In this paper the responses of seated human body under vertical vibration were studied by biodynamic equations of STH, DPM, apparent mass in frequency range, and the acceleration of human body organs were optimized in 3.5, 5.0 and 10 HZ. Frequencies

This study the input stimulus equation is defined as

$$U = 0.05 \sin(2\pi f t)$$

The STH equation is the amount of vibration transferred to the body, as much as one can reduces the STH magnitude the drivers comfort will be increased.

Figure (2) shows the biodynamic STH equation as can be seen from this figure except in the frequency range 1.6 – 2.2 HZ. The STH function in the case of optimized seat is reduced substantially.

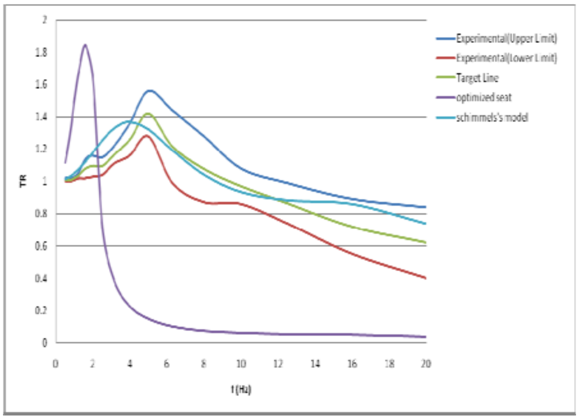

Figure 2. STH biodynamical function, comparing numerical and experimental results

Figure 3 through 9 shows the reduction of transferred acceleration to the seated body which means that the transferred forces are reduced as the driver comfort is increased.

The acceleration of pelvis and head in 3.5 HZ, 5 HZ and 10 HZ frequencies are shown in frequencies 5 through 10.

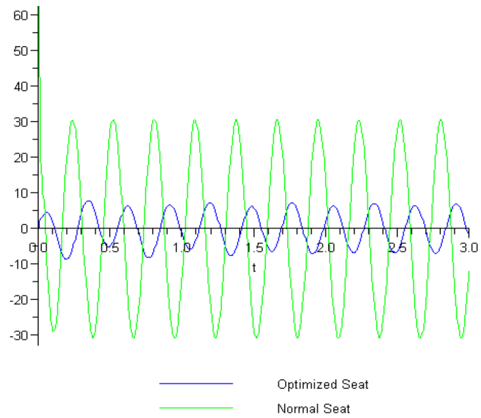

Figure 3. comparing numerical results of pelvis acceleration in 3.5 Hz at normal and optimized seat

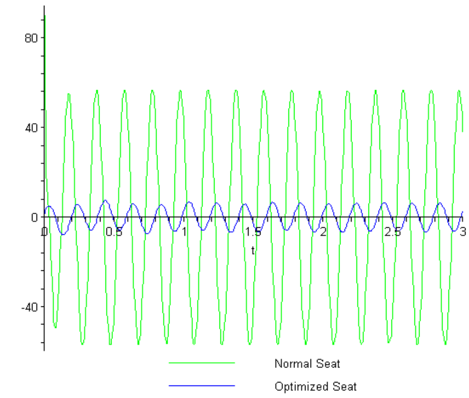

Figure 4. comparing numerical results of pelvis acceleration in 5 Hz at normal and optimized seat

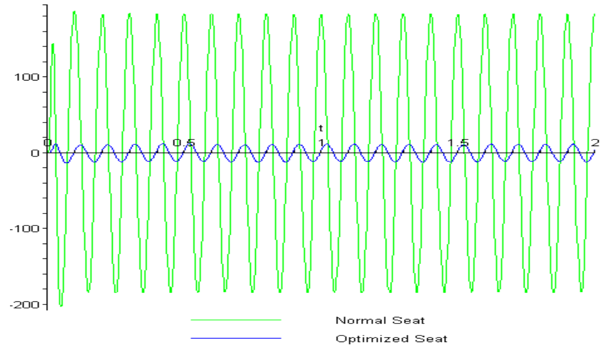

Figure 7. comparing numerical results of head acceleration in 5 Hz at normal and optimized seat

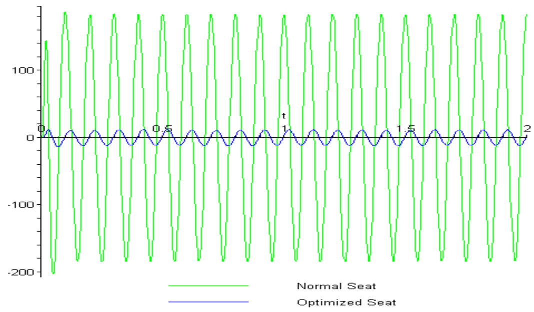

Figure 5. comparing numerical results of pelvis acceleration in 10 Hz at normal and optimized seat

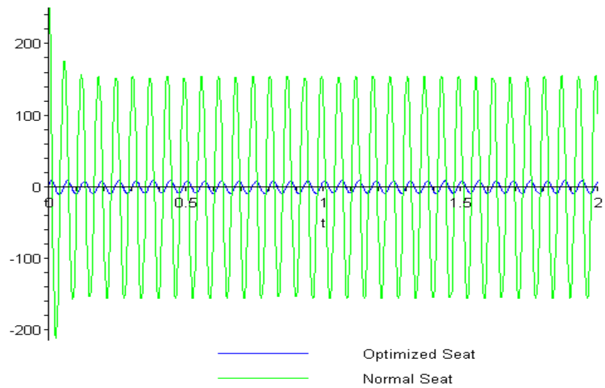

Figure 8. comparing numerical results of head acceleration in 10 Hz at normal and optimized seat

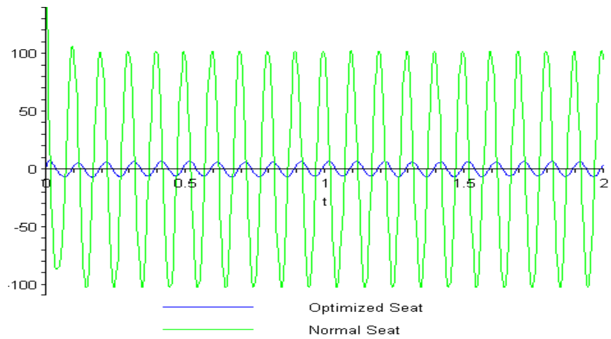

Figure 6. comparing numerical results of head acceleration in 3.5 Hz at normal and optimized seat

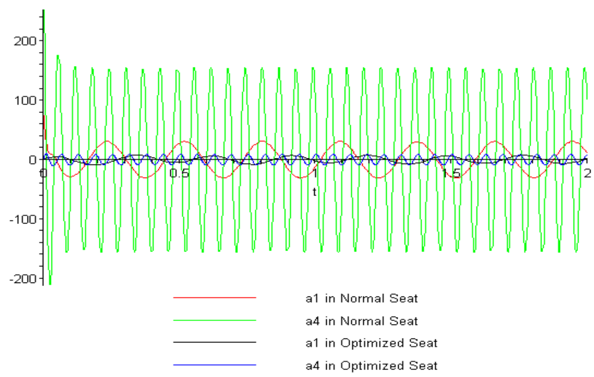

Figure 9. comparing numerical results of pelvis acceleration (a_1) and head (a_2) in 3.5 Hz at normal and optimized seat

SUMMARY

Due to optimization of biodynamic function STH, this function show a substantial reduction which be as reduction of transferred vibration to the body.

Impedance and apparent mass function has no reduction became the optimization was not based on these functions. (Fig. 3 & 4)

REFERENCES

M. Harris, Shock and Vibration Handbook, New York, McGraw-Hill, 1988.

R. R. Coerman, "The Mechanical Impedance of Human Body in Sitting and Standing Position at Low frequencies", Human Factors, Vol. 4, pp. 227-253.

C. W. Suggs, C. F. Abrams and L. F. Stikeleather, "Application of a Damped Spring-Mass Human vibration Simulator in Vibration Testing of Vehicle Seats", Ergonomics, Vol. 12, pp. 79-90, 1969.

R. Muksian and C. D. Nash, "A Model For Response of Seated Humans To Sinusoidal Displacements of The Seat", J. Biomech., Vol. 7, pp. 209-215, 1974.

R. Muksian and C. D. Nash, "On Frequency-Dependent Damping Coefficients in Lamped-Parameter Models of Human Beings, J. Biomech., Vol. 9, pp. 339-342, 1976.

M. K. Patil and M. S. Palanichamy, "A Mathematical Model of Tractor-Occupant System With a New Suspension for minimization of Vibration Response", Appl. Math. Model., Vol. 12, pp. 63-71, 1988.

M. K. Patil, M. S. Palanichamy and D. N. Ghista, "Man-Tractor System Dynamics: Toward a Better Suspention System for Human Ride Comfort", J. Biomech., Vol. 11, pp. 397-406, 1978.

W. Qassem, "Model Prediction of Vibration Effects on Human Subject Seated on Various Cushions, Med. Eng. and Phys., Vol. 18, No. 5, pp. 350-359, 1996.

W. Qassem, M. O. Othman and S. Abdul-Majeed, " The Effects of Vertical and Horizontal Vibrations on the Human Body", Med. Eng. Phsy., Vol. 16, pp. 151-161,1994

Y. Wan, J. M. Schimmels, "A Simple That Captures the Essential Dyamics of a Seated Human Exposed to Whole Body Vibration", Adv. Biomech., ASME, BED 31, pp. 333-334, 1995.