THE CHOSEN PARAMETERS OF A PASSIVE DAMPING SYSTEM BASED ON STOCHASTIC OPTIMIZATION ALGORITHM

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SUMMARY

The vehicle systems usually employ the passive damping device to dispose of an oscillation. In passive damper, it is important to choose the design parameters (*the stiffness of spring and coefficient of damper*) so that the oscillation target of vehicle is the best in the operating conditions (*typical load mode, the working speed range, typical street*). In this paper, the author proposes a solution to choose the design parameters based on a stochastic optimization algorithm which is assumed that this device is an active damper (*the damping device is controlled by an electronic control system*). According to design parameters of the passive damper are found by a covariance matrix and an equation order reduction. The results of proposed method are positive approach which is proven by the simulation results. Thereby, it will open a possibility for practical applications.

Key word: *damping system, stochastic optimization, LQG, covariance matrix*

INTRODUCTION

With the development of electronics and microprocessors, commercial auto – mobiles with active dampers become available in the 1990s. Although active damper can improve the ride comfort and road handing beyond that attainable by passive damper, the cost, weight, and power requirments of active dampers remain prohibitive. Because, passive dampers are simple, reliable, and inexpensive, they remain dominant in automotive marketplace.

When the vehicles move on the street, there are many factors which affect the vehicle for example: actual velocity, aerodynamic drag, road conditions,... they usually change with the times and effect to the oscillation standards of the vehicle. The oscillation vehicle will a constant or a little changing when it is affected by above factors, the stiffness of spring and coefficient of damper must have suitable values.

There have appeared relatively few studies on optimization of the passive dampers. Li and Pin [1] employed evolutionary algorithms to optimize a passive quarter-car suspension. Optimization of a quarter-car suspension is formulated as an H_2 optimal control problem by Corriga et al [2] and a simplex direct search is employed to find the optimum values of two parameters. Camino et al [3] applied a linear – matrix – inequality (LMI) base min/max algorithm for static output feedback to design of passive the optimal quarter-car suspension.

By minimizing the variance of control force difference between the passive suspension and the LQG active suspension with full-state feedback. Lin and Zhang [4] obtain the suboptimal parameters of LQG passive suspensions based on half car-model. Elamadany [5] developed a procedure based on covariance analysis and direct search method to optimize the passive suspension of the three-axle half vehicle model. Castillo et al [6] use sequential linear programming to minimize the weighted acceleration of passenger subject to constraint on the suspension stroke.

In this paper, we use a stochastic optimization algorithm to find design parameters of the passive damper applied covariance matrix in [5] and equation order reduction in [7]

We consider the passive damping system which is described in Figure 1.

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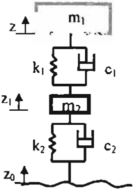

Figure 1. *The passive damping system*

Table 1. *The parameters of the passive damping system [3]*

Parameters	Meaning
$m_1 = 500(kg)$	The weight of truck
$m_2 = 63(kg)$	The weight of tyre
k_1	The stiffness of spring
c_1	The coefficient of damper
$k_2 = 230(kN/m)$	The stiffness of tyre
$c_2 = 120(Ns/m)$	The damping coefficient the tyre

First, model of the system based on D'Alambe priciple

$$\begin{cases} m_1\ddot{z} + k_1(z - z_1) + c_1(\dot{z} - \dot{z}_1) = 0 \\ -m_2\ddot{z}_1 + \left|k_1(z - z_1) + c_1(\dot{z} - \dot{z}_1)\right| - \dots \\ \dots - \left|k_2(z_1 - z_0) + c_2(\dot{z}_1 - \dot{z}_0)\right| = 0 \end{cases} \quad (1.1)$$

$$\begin{cases} \dot{x}_1 = x_2 \\ \dot{x}_2 = -\frac{k_1}{m_1}(x_1 - x_3) - \frac{c_1}{m_1}(x_2 - x_4) + \frac{1}{m_1}u \\ \dot{x}_3 = x_4 \\ \dot{x}_4 = \frac{k_2}{m_2}x_1 + \frac{c_1}{m_2}x_2 - \frac{k_1 + k_2}{m_2}x_3 - \frac{c_1 + c_2}{m_2}x_4 + \\ + \frac{k_2}{m_2}w_1 + \frac{c_2}{m_2}w_2 - \frac{1}{m_2}u \end{cases} \quad (1.2)$$

The mathematical expression in statement space form as given in Formula (1.3).

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \\ \dot{x}_4 \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 & 0 \\ -\frac{k_1}{m_1} & -\frac{c_1}{m_1} & \frac{k_1}{m_1} & \frac{c_1}{m_1} \\ 0 & 0 & 0 & 1 \\ \frac{k_1}{m_2} & \frac{c_1}{m_2} & -\frac{k_1 + k_2}{m_2} & -\frac{c_1 + c_2}{m_2} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{1}{m_1} \\ 0 \\ -\frac{1}{m_2} \end{bmatrix} u + \begin{bmatrix} 0 \\ 0 \\ \frac{k_2}{m_2} \\ \frac{c_2}{m_2} \end{bmatrix} \underline{w}$$

$$\dot{\underline{x}} = A_r\underline{x} + B_r u + D_r\underline{w}$$

$$A_r = \begin{bmatrix} 0 & 1 & 0 & 0 \\ -\frac{k_1}{m_1} & -\frac{c_1}{m_1} & \frac{k_1}{m_1} & \frac{c_1}{m_1} \\ 0 & 0 & 0 & 1 \\ \frac{k_2}{m_2} & \frac{c_1}{m_2} & -\frac{k_1 + k_2}{m_2} & -\frac{c_1 + c_2}{m_2} \end{bmatrix}$$

$$B_r = \begin{bmatrix} 0 \\ \frac{1}{m_1} \\ 0 \\ -\frac{1}{m_2} \end{bmatrix}; \quad D_r = \begin{bmatrix} 0 \\ 0 \\ \frac{k_2}{m_2} \\ \frac{c_2}{m_2} \end{bmatrix} \quad (1.3)$$

The equation expression for the stochastic surface road is given in Formula (1.4):

$$\dot{w} = -avw + \xi(t)$$
$$E\{\xi(t), \xi(t)\} = 2\sigma^2 av\delta(t - \tau) = Q\delta(t - \tau) \quad (1.4)$$
$$\dot{w} = A_w w + D_w\xi(t);\ A_w = -av;\ D_w = 1$$

Table 2. *The parameters of the stochastic surface road [7]*

Parameters	Meaning
$a = 0.15(m^{-1})$	The specific coefficient of surface road
$v = 10 \div 40(m/s)$	The speed of vehicle
w	spectral density function
$\sigma^2 = 9(mm^2)$	The specific coefficient of stochastic
δ	dirac

Second, we combine the Formula (1.3) with (1.4) to describe the general mathematical model which mentions the stochastic factors of the surface road:

$$\begin{pmatrix} \dot{\underline{x}} \\ \dot{\underline{w}} \end{pmatrix} = \begin{pmatrix} A_r & D_r \\ \Theta & A_w \end{pmatrix} \begin{pmatrix} \underline{x} \\ \underline{w} \end{pmatrix} + \begin{pmatrix} B_r \\ \Theta \end{pmatrix} \underline{u} + \begin{pmatrix} \Theta \\ D_w \end{pmatrix} \underline{\xi}(t)$$
$$\dot{\underline{x}}_q = A\underline{x}_q + B\underline{u} + D\underline{\xi}(t);\ \underline{x}_q = \begin{pmatrix} \underline{x} \\ \underline{w} \end{pmatrix} \quad (1.5)$$

Problems: we find parameters of the passive damping system c_1 and k_1 with assume that we know the parameter values as m_1; m_2; k_2; c_2.

The proposed solution : It is assumed that this system is an active damper which it is controlled by LQR optimization in [5].

- The model of the system

$$\dot{\underline{x}}_q = A\underline{x}_q + B\underline{u} + D\underline{\xi}(t)$$

- The controller

$\underline{u} = -R\underline{x}$

with $R = F^{-1}(N^T + B^T.S)$ is defined by solving Riccati equation:

$$S(A - BF^{-1}N^T) + (A - BF^{-1}N^T)^T S - $$
$$-SBF^{-1}B^T S + (E - NF^{-1}N^T) = 0$$

- The objective function :

$$J = \int_0^T \left[\left|\underline{x}^T E\underline{x} + \underline{u}^T F\underline{u}\right| + 2\underline{u}^T N^T \underline{x}^T\right] dt \to \min \quad (1.6)$$

The following steps are necessary to choose the parameters c_i and k_i : *the first*, we build the objective functions which correlate with criteria evaluation of the oscillation, and setup the general objective function which form the Formula (1.6), *the second*, it used reduced method to solve Riccati and Lyapunov function defining S matrix and X matrix, *the last*, we find two matrix A and R to substitute the objective function which defines coefficients c_i and k_i .

PERFORMENCE

The objective function

We define optimal parameters which concern with criteria evaluation of the oscillation: the smooth motion, the fast ability stick to surface road and working space of the suspend system. Therefore, the target funtion is given in the Formula (2.1):

$$J = \rho_1 J_1 + \rho_2 J_2 + \rho_3 J_3 + \rho_4 J_4 \to \min \quad (2.1)$$

where :

J_1 : The target funtion evaluates the smooth motion

J_2 : The target funtion evaluates the relative shift between the vehicle body and wheels.

J_3 : The target funtion evaluates the relative shift between the wheels and surface road.

J_4 . The energy costs of the controlled function

$\rho_i(i = 1,2,3,4)$: The equivalent weights of the target functions.

The objective function J_1. The smooth motion evaluates based on the average squared acceleration of the passenger compartment.

$J_1 = E\{\ddot{y}_1^2\} = E\{\dot{x}_2^2\} \to \min$ with E is a mathematical expectation

$$\dot{x}_2 = \sum_{i=1}^{5} A(2,i)x_i + \frac{1}{m_1}$$
$$= \sum_{i=1}^{5}\left[A(2,i) - \frac{1}{m_1}R(i)\right]x_i \quad (2.2)$$
$$J_1 = E\left[\left(\sum_{i=1}^{5}\left[A(2,i) - \frac{1}{m_1}R(i)\right]x_i\right)^2\right]$$

$$J_1 = \sum_{i=1}^{5}\sum_{j=1}^{5}\left[A(2,i) - \frac{1}{m_1}R(i)\right]\left[A(2,j) - \frac{1}{m_1}R(i)\right]E(x_i,x_j)$$
$$= \sum_{i=1}^{5}\sum_{j=1}^{5}\left[A(2,i) - \frac{1}{m_1}R(i)\right]\left[A(2,j) - \frac{1}{m_1}R(i)\right]X(i,j)$$

The objective function J_2. This evaluates are the average squared acceleration of the relative shift between the vehicle body and wheels.

$$J_2 = E\left\{(y_1 - y_2)^2\right\} = E\left\{(x_1 - x_3)^2\right\} \to \min$$
$$= E\{x_1x_1 - 2x_1x_3 + x_3x_3\} \quad (2.3)$$
$$= X(1,1) - 2X(1,3) + X(3,3)$$

The objective function J_3. This evaluates are the average squared acceleration of the relative shift between the wheels and surface road.

$$J_3 = E\left\{(y_2 - y_0)^2\right\} = E\left\{(x_3 - x_5)^2\right\} \to \min$$
$$= E\{x_3x_3 - 2x_5x_3 + x_5x_5\} \quad (2.4)$$
$$J_1 = X(3,3) - 2X(3,5) + X(5,5)$$

The objective function J_4. The energy costs of the controlled function

$$J_4 = E\{u^2\} = E\left\{(R(i)x_i)^2\right\} \to \min$$
$$= \sum_{i=1}^{5}\sum_{j=1}^{5} R(i)R(j)X(i,j) \quad (2.5)$$

The following, the general objective function J is in the form Formula (1.6)

$$J = \rho_1 J_1 + \rho_2 J_2 + \rho_3 J_3 + \rho_4 J_4$$
$$= \rho_1 E\{\ddot{y}_1^2\} + \rho_2 E\left\{(y_1 - y_2)^2\right\} + \rho_3 E\left\{(y_2 - y_0)^2\right\} + \rho_4 E\{u^2\}$$
$$= E\left\{\rho_1 \ddot{z}_1^2 + \rho_2(z_1 - z_2)^2 + \rho_3(z_2 - z_0)^2 + \rho_4 u^2\right\}$$

$$J = E\left\{\begin{array}{l}\rho_1\left[-\frac{k_1}{m_1}(x_1 - x_3) - \frac{c_1}{m_1}(x_2 - x_4) + \frac{1}{m_1}u\right]^2 \\ +\rho_2(x_1 - x_3)^2 + \rho_3(x_3 - x_5)^2 + \rho_4 u^2\end{array}\right\}$$

$$= E\left\{\rho_1\left(\frac{k_1^2}{m_1^2}x_1^2 + \frac{c_1^2}{m_1^2}x_2^2 + \frac{k_1^2}{m_1^2}x_3^2 + \frac{c_1^2}{m_1^2}x_4^2 + \frac{1}{m_1^2}u^2\right.\right.$$

$$-\frac{k_1^2}{m_1^2}x_1x_3 - 2\frac{k_1c_1}{m_1^2}x_1x_4 - 2\frac{k_1}{m_1^2}x_1u - 2\frac{k_1c_1}{m_1^3}x_2x_3$$

$$\left.-2\frac{c_1^2}{m_1^2}x_2x_4 + 2\frac{k_1c_1}{m_1^2}x_3x_2 + 2\frac{k_1c_1}{m_1^2}x_3x_4 + 2\frac{k_1}{m_1^2}x_3u + 2\frac{c_1}{m_1^2}x_4u\right)$$

$$\left.+\rho_2\left(x_1^2 - 2x_1x_3 + x_3^2\right) + \rho_3\left(x_3^2 - 2x_3x_5 + x_5^2\right) + \rho_1u^2\right\}$$

$$= E\left\{\begin{bmatrix}x_1\\x_2\\x_3\\x_4\\x_5\end{bmatrix}^T \begin{vmatrix}\rho_1\frac{k_1^2}{m_1^2}+\rho_2 & \rho_1\frac{k_1c_1}{m_1^2} & -\rho_1\frac{k_1^2}{m_1^2}-\rho_2 & -\rho_1\frac{k_1c_1}{m_1^2} & 0\\ \rho_1\frac{k_1c_1}{m_1^2} & \rho_1\frac{c_1^2}{m_1^2} & -\rho_1\frac{k_1c_1}{m_1^2} & -\rho_1\frac{c_1^2}{m_1^2} & 0\\ -\rho_1\frac{k_1^2}{m_1^2}-\rho_2 & -\rho_1\frac{k_1c_1}{m_1^2} & \rho_1\frac{k_1^2}{m_1^2}+\rho_2+\rho_3 & \rho_1\frac{k_1c_1}{m_1^2} & -\rho_3\\ -\rho_1\frac{k_1c_1}{m_1^2} & -\rho_1\frac{c_1^2}{m_1^2} & \rho_1\frac{k_1c_1}{m_1^2} & \rho_1\frac{c_1^2}{m_1^2} & 0\\ 0 & 0 & -\rho_3 & 0 & -\rho_3\end{vmatrix}\begin{bmatrix}x_1\\x_2\\x_3\\x_4\\x_5\end{bmatrix}+\right.$$

$$\left.+\underline{u}^T\left[\frac{1}{m_1^2}+\rho_1\right]\underline{u} + 2\underline{u}\begin{vmatrix}-\rho_1\frac{k_1}{m_1^2} & -\rho_1\frac{c_1}{m_1^2} & \rho_1\frac{k_1}{m_1^2} & \rho_1\frac{k_1}{m_1^2} & 0\end{vmatrix}\begin{vmatrix}x_1\\x_2\\x_3\\x_4\\x_5\end{vmatrix}\right\}$$

Comparision with the Formula (1.6), we have:

$$E = \begin{vmatrix}\rho_1\frac{k_1^2}{m_1^2}+\rho_2 & \rho_1\frac{k_1c_1}{m_1^2} & -\rho_1\frac{k_1^2}{m_1^2}-\rho_2 & -\rho_1\frac{k_1c_1}{m_1^2} & 0\\ \rho_1\frac{k_1c_1}{m_1^2} & \rho_1\frac{c_1^2}{m_1^2} & -\rho_1\frac{k_1c_1}{m_1^2} & -\rho_1\frac{c_1^2}{m_1^2} & 0\\ -\rho_1\frac{k_1^2}{m_1^2}-\rho_2 & -\rho_1\frac{k_1c_1}{m_1^2} & \rho_1\frac{k_1^2}{m_1^2}+\rho_2+\rho_3 & \rho_1\frac{k_1c_1}{m_1^2} & -\rho_3\\ -\rho_1\frac{k_1c_1}{m_1^2} & -\rho_1\frac{c_1^2}{m_1^2} & \rho_1\frac{k_1c_1}{m_1^2} & \rho_1\frac{c_1^2}{m_1^2} & 0\\ 0 & 0 & -\rho_3 & 0 & -\rho_3\end{vmatrix}$$

$$F = \left(\frac{1}{m_1^2} + \rho_4\right)$$

$$N^T = \begin{vmatrix}-\rho_1\frac{k_1}{m_1^2} & -\rho_1\frac{c_1}{m_1^2} & \rho_1\frac{k_1}{m_1^2} & \rho_1\frac{k_1}{m_1^2} & 0\end{vmatrix} \quad (2.6)$$

Solving stochastic optimization problem

The solving stochastic optimization problem susbtance is that Riccati and Lyapunov equations are solved to define S and X matrixs.

The Riccati equation is defined that:

$$S\left(A - BF^{-1}N^T\right) + \left(A - BF^{-1}N^T\right)^T S - $$
$$- SBF^{-1}B^TS + \left(E - NF^{-1}N^T\right) = 0$$

To define S matrix, the equation order reduction is reduced.

The separate S, E, N, A, B and D matrixs, we obtain :

$$S = \begin{vmatrix}S_{xx} & S_{xw}\\ S_{xw}^T & S_{ww}\end{vmatrix}; E = \begin{vmatrix}E_{xx} & E_{xw}\\ E_{xw}^T & E_{ww}\end{vmatrix}; N = \begin{vmatrix}N_x\\ 0\end{vmatrix}$$
$$A = \begin{vmatrix}A_x & D_x\\ 0 & A_w\end{vmatrix}; B = \begin{vmatrix}B_x\\ 0\end{vmatrix}; D = \begin{vmatrix}0\\ D_w\end{vmatrix} \quad (2.7)$$

Substitute (2.7) to Riccati equation

$$\begin{bmatrix}S_{xx} & S_{xw}\\ S_{xw}^T & S_{ww}\end{bmatrix}\left(\begin{bmatrix}A_x & D_x\\ 0 & A_w\end{bmatrix} - \begin{bmatrix}B_x\\ 0\end{bmatrix}F^{-1}\begin{bmatrix}N_x\\ 0\end{bmatrix}^T\right) +$$
$$+\left(\begin{bmatrix}A_x & D_x\\ 0 & A_w\end{bmatrix} - \begin{bmatrix}B_x\\ 0\end{bmatrix}F^{-1}\begin{bmatrix}N_x & 0\end{bmatrix}\right)^T\begin{bmatrix}S_{xx} & S_{xw}\\ S_{xw}^T & S_{ww}\end{bmatrix} -$$
$$-\begin{bmatrix}S_{xx} & S_{xw}\\ S_{xw}^T & S_{ww}\end{bmatrix}\begin{bmatrix}B_x\\ 0\end{bmatrix}F^{-1}\begin{bmatrix}B_x & 0\end{bmatrix}\begin{bmatrix}S_{xx} & S_{xw}\\ S_{xw}^T & S_{ww}\end{bmatrix} + \quad (2.8)$$
$$+\left(\begin{bmatrix}E_{xx} & E_{xw}\\ E_{xw}^T & E_{ww}\end{bmatrix} - \begin{bmatrix}N_x\\ 0\end{bmatrix}F^{-1}\begin{bmatrix}N_x & 0\end{bmatrix}\right) = 0$$

The result, four equations are obtained :

$$S_{xx}\left(A_x - B_xF^{-1}N_x^T\right) + \left(A_x - B_xF^{-1}N_x^T\right)^T S_{xx} -$$
$$-S_{xx}B_xF^{-1}B_x^TS_{xx} + E_{xx} - N_xF^{-1}N_x^T = 0 \quad (2.10)$$

(2.10) is the Riccati equation

$$S_{xx}D_x + E_{xw} +$$
$$+S_{xw}\left|A_w + \left(A_x - B_xF^{-1}N_x^T\right)^T - S_{xx}B_xF^{-1}B_x^T\right| = 0 \quad (2.11)$$

(2.11) is the normal algebraic equation

$$S_{xw}^TA_w^T + D_x^TS_{xx} + E_{xw}^TS_{xw}^T +$$
$$+\left[\left(A_x - B_xF^{-1}N_x^T\right) - B_xF^{-1}B_x^TS_{xx}\right] = 0 \quad (2.12)$$

(2.12) is the normal algebraic equation

$$S_{ww}A_w + A_w^TS_{ww}^T +$$
$$+\left(S_{xw}^TD_x + D_x^TS_{xw} + S_{xw}^TB_xF^{-1}B_x^TS_{xw} + E_{ww}\right) = 0 \quad (2.13)$$

(2.13) is the Lyapunov equation

where S_{xx}; S_{xw}; S_{xw}^T; and S_{ww} are roots of (2.10), (2.11), (2.12), (2.13)

Next, Lyapunov equation is solved to define covariance matrix of state vector as given:

$$(A - BR)X + X(A - BR)^T + DQD^T = 0 \quad (2.14)$$

To define X matrix, the equation order reduction is reduced and X, R, A, B and D matrixs are seperated:

$$X = \begin{bmatrix} X_{zz} & X_{zw} \\ X_{zw}^T & X_{ww} \end{bmatrix}; R = \begin{bmatrix} R_z \\ R_w \end{bmatrix}; A = \begin{bmatrix} A_z & D_z \\ 0 & A_w \end{bmatrix} \quad (2.15)$$
$$B = \begin{bmatrix} B_z \\ 0 \end{bmatrix}; D = \begin{bmatrix} 0 \\ D_w \end{bmatrix}$$

Substitute (2.15) to Lyapunov equation (2.14). The result, the equations are obtained :

$$\Leftrightarrow (A_z - B_z R_z) X_{zz} + X_{zz}(A_z - B_z R_z)^T + (D_z - B_z R_w) X_{zw}^T + X_{zw}(D_z - B_z R_w)^T = 0 \quad (2.16)$$

(2.16) is the Lapunov equation

$$(A_z - B_z R_z) X_{zw} + (D_z - B_z R_w) X_{ww} + X_{zw} A_w^T = 0 \quad (2.17)$$

is the normal algebraic equation (2.17)

$$A_w X_{ww} + X_{ww} A_w^T + D_w Q D_w^T = 0 \quad (2.18)$$

(2.18) is the Lapunov equation

where X_{zz}; X_{zw} and X_{zw}^T; X_{ww} are roots of (2.16), (2.17), (2.18).

With R matrix define in the Formula (2.19):

$$R = \begin{bmatrix} R_z \\ R_w \end{bmatrix}^T; R_z = F^{-1}(N_z^T + B_z^T S_{zz}); R_w = F^{-1} B_z^T S_{zw}$$

The results are obtained by the algorithm which presents in Figure 4

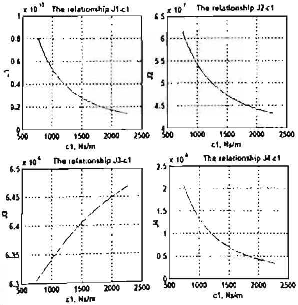

Figure 2. *The relationship between c_1 and $J_{1,2,3,4}$*

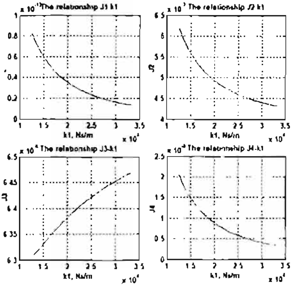

Figure 3. *The relationship between k_1 and $J_{1,2,3,4}$*

If k_1 is increased, then the objective function J_1 is decreased that the average squared acceleration of the passenger compartment is minimum *(see Fig 2)*. However, If k_1 is increased *(see Fig 2)*, then the objective function J_3 is increased following that the working space of the suspend system is extended so that the stiffness of spring makes decreasing smooth motion *(see Fig6)*.

The coefficient of damper c_1 effect to the oscillation standards of the vehicle. If c_1 is increased *(see Fig 2. and Fig 5)*, then a good ride comfort and road handling is extended, and the working space is smaller. Therefore, the design of the passive damping system is chosen:

$k_1 = 2.2871e^4 \, (kN/m)$

and $c_1 = 1.2871e^3 \, (Ns/m)$.

CONCLUSION

The calculation results show that the oscillation criteria of the passive damper systems are optimized corresponding to the design parameters *(contain c_1 and k_1)* based on optimal control algorithm LQR. This proves the assumption that the damping passive is active damper system is correct. Then, the equation order reduction is reduced to solve Riccati equation and Lyapunov equation.

The paper presents details of the process which is established the objective function by the actual requirements and is given as similar the Formula (1.6) instead of a constant matrix of the objective function as usual.

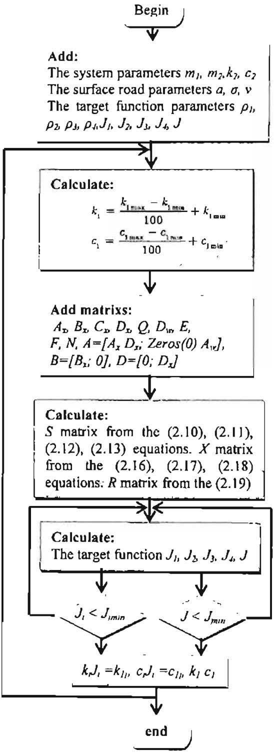

Figure 4. *The algorithm to find desing parameters*

With the optimal parameters c_1 and k_1, the criteria of the smooth motion, the ability stick fast to surface road and working space of the suspend system are better (*see Fig 2, Fig 3, Fig 4 and Fig 5*). This allows that the preliminary designing damper system is ensured reliability.

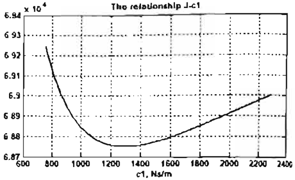

Figure 5. *The relationship between c_1 and J*

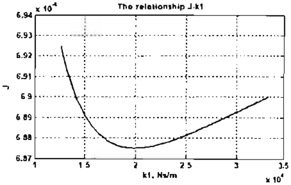

Figure 6 *The relationship between k_1 and J*

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TÓM TẮT

XÁC ĐỊNH THAM SỐ CHO HỆ THỐNG GIẢM CHẤN THỤ ĐỘNG BẰNG PHƯƠNG PHÁP TỐI ƯU NGẪU NHIÊN

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Trong các hệ thống dao động đặc biệt là hệ thống giảm chấn thụ động, việc quan trọng là lựa chọn các tham số thiết kế (*độ cứng nhíp và hệ số cản của giảm chấn*) sao cho các chỉ tiêu dao động của xe đạt giá trị tốt nhất trong điều kiện vận hành (*chế độ tải đặc trưng, dải tốc độ làm việc, loại đường vận hành phổ biến*). Trong bài báo này tác giả sẽ đề xuất một giải pháp lựa chọn các tham số thiết kế dựa trên thuật toán tối ưu ngẫu nhiên bằng cách giả thiết rằng hệ thống giảm chấn là tích cực (*hệ thống giảm chấn được điều khiển bởi một hệ điều khiển điện tử*). Theo đó, các tham số thiết kế của hệ thống giảm chấn thụ động sẽ được xác định dựa trên ma trận covariance và phương pháp giảm bậc phương trình. Kết quả của phương pháp rất khả quan thể hiện qua các kết quả mô phỏng, qua đó mở ra khả năng ứng dụng vào thực tế.

Từ khóa: *Hệ thống giảm chấn, tối ưu ngẫu nhiên, LQG, ma trận convariance*

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