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MODAL ANALYSIS OF QUARTER CAR MODEL SUSPENSION SYSTEM

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ABSTRACT

Suspension system is very important for comfort driving and travelling of the passengers. Therefore, this study provides a numerical tool for modeling and analyzing of a two degree of freedom quarter car model suspension system. Modal analysis places a vital role in designing the suspension system. In this paper presented the modal analysis of quarter car model suspension system by considering the undamped and damped factors. The modal and vertical equations of motions describing the suspension system were then solved theoretically for damping cases. The program was used successfully to solve the actual coupled equations and to plot the results.

KEYWORDS:Modal analysis, quarter car model, suspension system, damping cases.

INTRODUCTION

Suspension is the system of tires, tire air, springs, shock absorbers and linkages that connects a vehicle to its wheels and allows relative motion between the two. Suspension systems serve a dual purpose — contributing to the vehicle's road holding/handling and braking for good active safety and driving pleasure, and keeping vehicle occupants comfortable and a ride quality reasonably well isolated from road noise, bumps, vibrations, etc. These goals are generally at odds, so the tuning of suspensions involves finding the right compromise. It is important for the suspension to keep the road wheel in contact with the road surface as much as possible, because all the road or ground forces acting on the vehicle do so through the contact patches of the tires. The suspension also protects the vehicle itself and any cargo or luggage from damage and wear. The design of front and rear suspension of a car may be different. The main role of suspension system is to support the weight of the vehicle, providing a smoother ride for the passengers, protecting the vehicle from damage, keeping the wheels firmly pressed to the ground for better traction and isolating the vehicle from road shocks. There are three basic components in any suspension system such as springs, anti-sway bars and dampers. Obviously any four wheel vehicle needs suspension for both the front wheels and the rear suspension, but in two wheel drive vehicles these can be very different configuration. For front-wheel drive cars, rear suspension has few constraints and a variety of beam axles and independent suspensions are used. For rear-wheel drive cars, rear suspension has many constraints and the development of the superior but more expensive independent suspension layout has been difficult. Four-wheel drive often have suspensions that are similar for both the front and rear wheels. Passive suspension system can be found in controlling the dynamics of vertical motion of a vehicle. There is no energy supplied by the suspension element to the system. Even though it doesn't apply energy to the system, but it controls the relative motion of the body to the wheel by using different types of damping or energy dissipating elements. Passive suspension has significant limitation in structural applications. The characteristic are determined by the designer according to the design goals and the intended application. The disadvantage of passive suspension system is it has fix characteristic, for example if the designer design the suspension heavily damped it will only give good vehicle handling but at the same time it transfer road input (disturbance) to the vehicle body. The result of this action is if the vehicle travel at the low speed on a rough road or at the high speed in a straight line, it will be perceived as a harsh road. Then, if the suspension is design lightly damped, it will give more comfortable ride. Unfortunately this design will reduce the stability of the vehicle in make turn and lane changing. Figure 1 shows traditional passive suspension components system that consists of spring and damper. For active control of a vehicle suspension system various approaches have been proposed in the literature. R.K.PeKgokgoz et. al investigated the fuzzy logic to control (FLC), the active suspension and the membership functions are optimized by using genetic algorithm operations. The model has been applied to a sample one quarter car model. The results of proposed model were compared with those of PID controller and the efficiency of the FLC controller model has been assessed. It has been shown that the fuzzy-logic controller displays better performance than the PID controller for both the minimization of the maximum body deflection and the efficiency of the actuator force of the controller[1]. M. Senthil Kumar et. al used the linear quadratic optimal control theory, based on two different control approaches [conventional method (CM), and acceleration dependent method (ADM)].

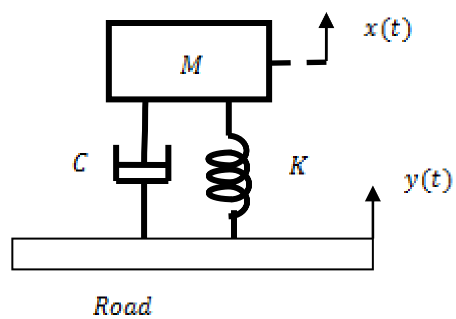

Figure .1 Passive suspension component

It was shown that active suspension system had a better potential to improve both the ride comfort and road holding, since the acceleration has been reduced for active CM system (19.58%) and for active ADM system (34.08%) compared to passive one[2]. Mouleeswaran et. al studied the active suspension system for the quarter car model by used a proportional integral derivative (PID) controller. The controller design deals with the selection of proportional, derivative gain and integral gain parameters. The results show that the active suspension system has reduced the peak overshoot of spring mass displacement, spring mass acceleration, suspension travel and tire deflection compared to passive suspension system[3]. Hedrick[4] considered a quarter car model with hydraulic actuator acting under the effect of coulomb friction. An absorber based nonlinear controller and adaptive nonlinear controller are proposed. Employing two sensors, one for displacement and other for velocity measurements, Gobbi et. al [5] studied dynamic behaviour of passively suspended vehicles running on rough roads. The road profile is considered to give random inputs to the suspension system. Ahmed Faheem [6] studied the dynamic behaviour using quarter car model and half car model for different excitations given by the road. Jacquelien et al. [7] used electrical analogy in conjunction with quarter car model and studied the control scheme of the suspension system. Wei Gao et al. [8] also studied the dynamic characteristics considering the mass, damping and tyre stiffness as random variables. Kamalakannan et al. [9] tried adaptive control by varying damping properties according to the road conditions. Sawant et al.[10]developed an experimental procedure for determining the suspension parameters using a quarter car model. Figure 1 represents the passive suspension sytem of quarter car model.

MATHEMATICAL MODELING

Traditionally automotive suspension designs have been a compromise between the three conflicting criteria of road holding, load carrying and passenger comfort. The suspension system must support the vehicle, provide directional control during handling maneuvers and provide effective isolation of passengers/payload from road disturbances.

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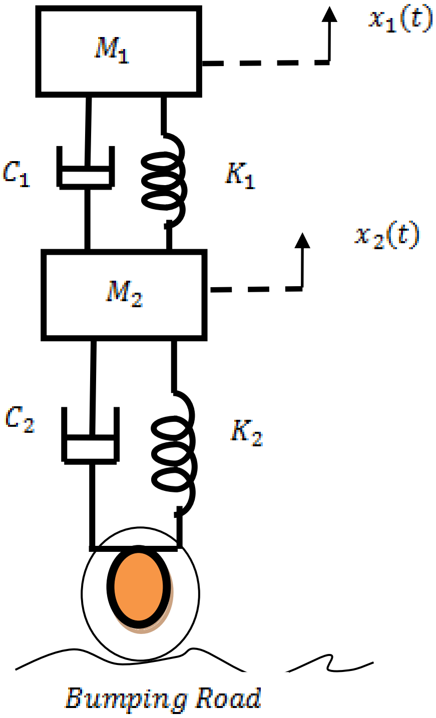

Figure.2 . Mathematical model of quarter car suspension system

Though a passive suspension system has the ability to store energy via a spring and to dissipate it via a damper. Its parameters are generally fixed, being chosen to achieve a certain level of compromise between road holding, load carrying and comfort . The work presented here tries to analyze the effect of seat suspension on vehicle performance of a quarter car model for a given road input using different approaches namely analysis by using state space equations in MATLAB, Where x_r, ,x_2 and x_1 are the vertical displacement of road, sprung mass and seat. Simulate the output response for sudden change in road profile of 0.2 m height as shown in figure 2. The following model parameters are considered as an attempt for studying the dynamic response of the suspension system. These values are closure to the available values from literature papers.

M_1-seat and driver mass (100Kg)

M_2-is the quarter of the vehicle sprung mass (230Kg)

C_1- Damping ratio of the seat suspension (2990Ns/m)

C_2- Damping ratio of the vehicle suspension (1990Ns/m)

K_1-seat suspension spring stiffness (7500N/m)

K_2-Vehicle suspension spring stiffness (27500N/m)

x_r=0.2 Road input (m)

Equations 1,2 and 3 are the equations of motions for seat mass, sprung mass and unsprung masses.

$$M_1\ddot{x}_1 + K_1\left(x_1 - x_2\right) + C_1\left(\dot{x}_1 - \dot{x}_2\right) = 0 \quad (1)$$

$$M_2\ddot{x}_2 + K_1\left(x_2 - x_1\right) + C_1\left(\dot{x}_2 - \dot{x}_1\right) + K_2(x_2 - x_r) + C_2\left(\dot{x}_2 - \dot{x}_r\right) = 0 \quad (2)$$

Equations 3 and 4 gives the modal response of the suspension system.

$$M_1\ddot{\eta}_1(t) + C_1\dot{\eta}_1(t) + \omega^2{}_1\eta_1(t) = 0 \quad (3)$$

$$M_2\ddot{\eta}_2(t) + C_2\dot{\eta}_2(t) + \omega^2{}_2\eta_2(t) = 0 \quad (4)$$

RESULTS AND DISCUSSION

From figures 3 to 8 describes the modal response and system response parameters such as displacement, velocity and accelerations of undamped suspension system. From figures 9 to 14 describes the modal response and system response parameters such as displacement, velocity and accelerations of damped suspension system. Generally researchers use Lyapunov'e method for stabilizing the damped suspension system. In this paper, results are presented through MATLAB code without using the above mentioned method. Results have been come closure to the outcome of the available literature presented.

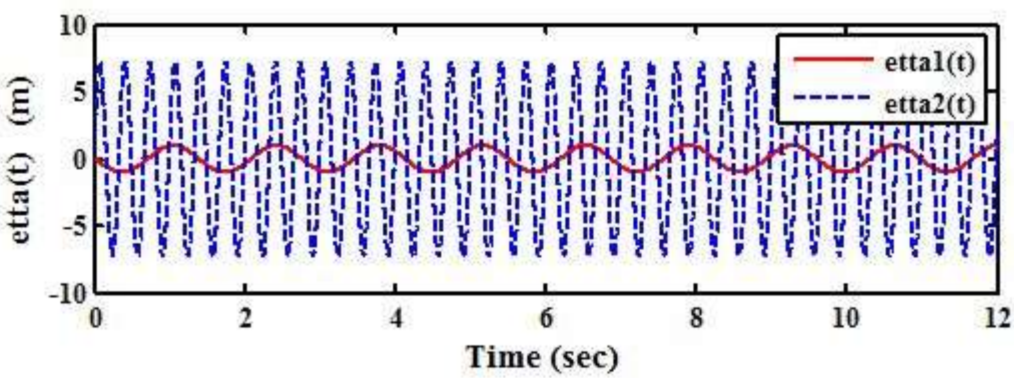

Figure.3 Undamped Modal response of η

Figure 3 describes the displacement of mass 2 is more than the mass one which is -6 to +6 m. And the displacement of mass one is -1 to +1 m. From figure 6,one can understand that the system response is in opposite to modal responses of masses.

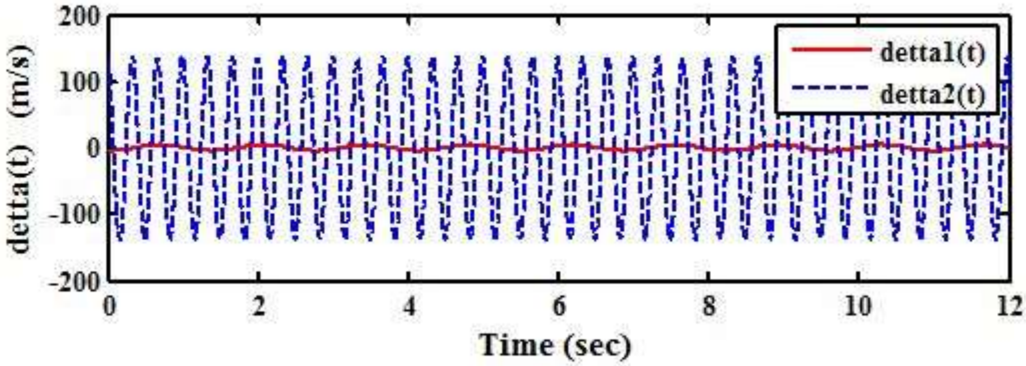

Figure.4 Undamped Modal response of $\dot{\eta}$

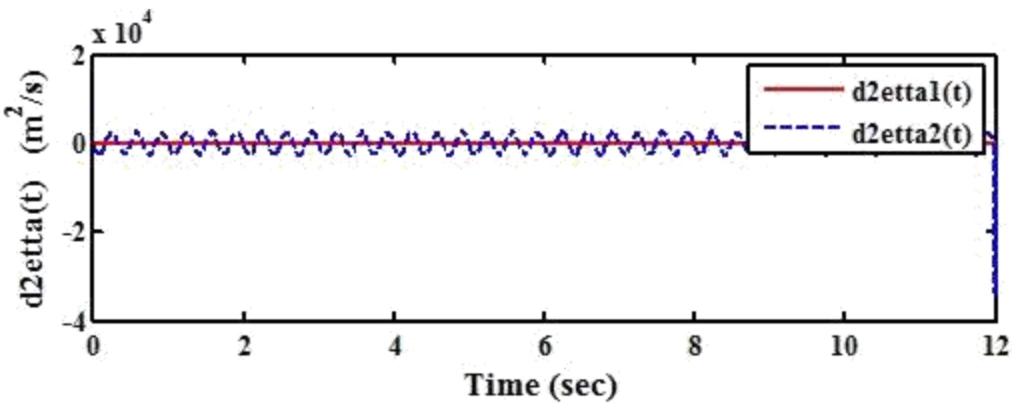

Figure.5 Undamped Modal response of $\ddot{\eta}$

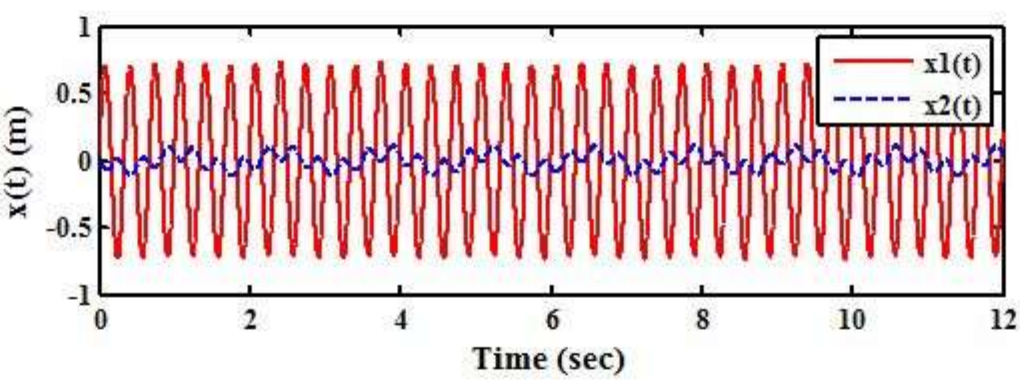

Figure.6Undamped System response of $x(t)$

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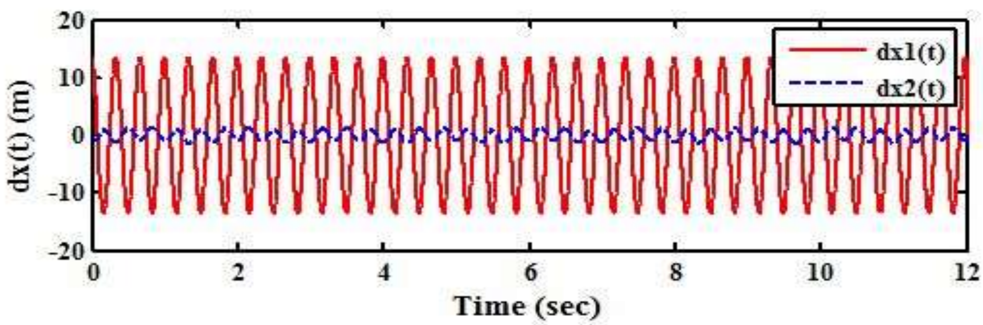

Figure.7 Undamped System response of $\dot{x}(t)$

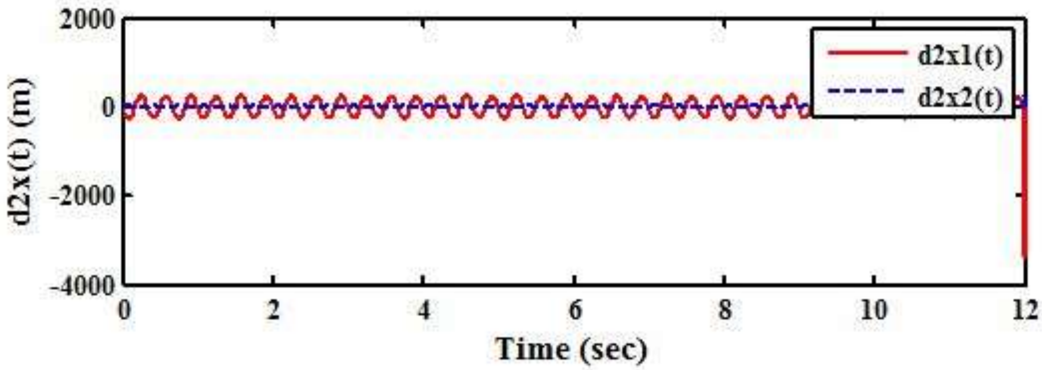

Figure. 8Undamped System response of $\ddot{x}(t)$

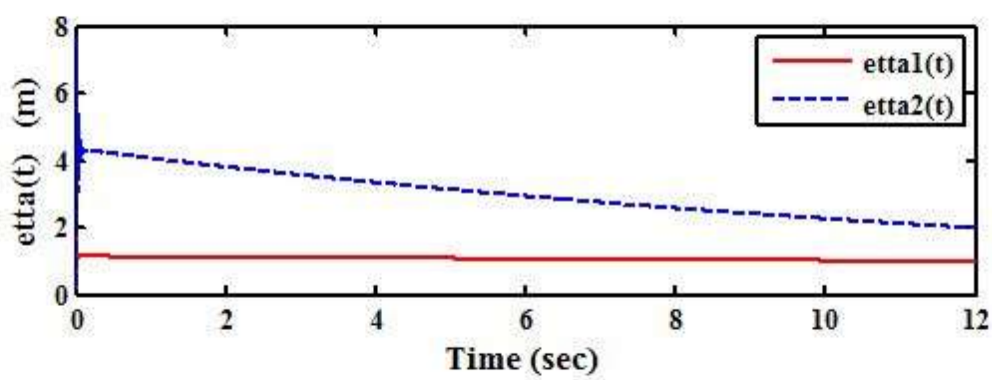

Figure. 9 Damped Modal response of η

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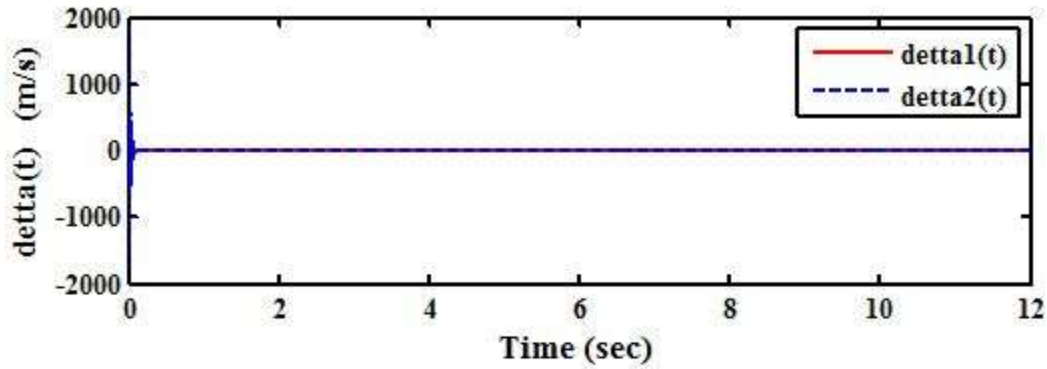

Figure.10 Damped Modal response of $\dot{\eta}$

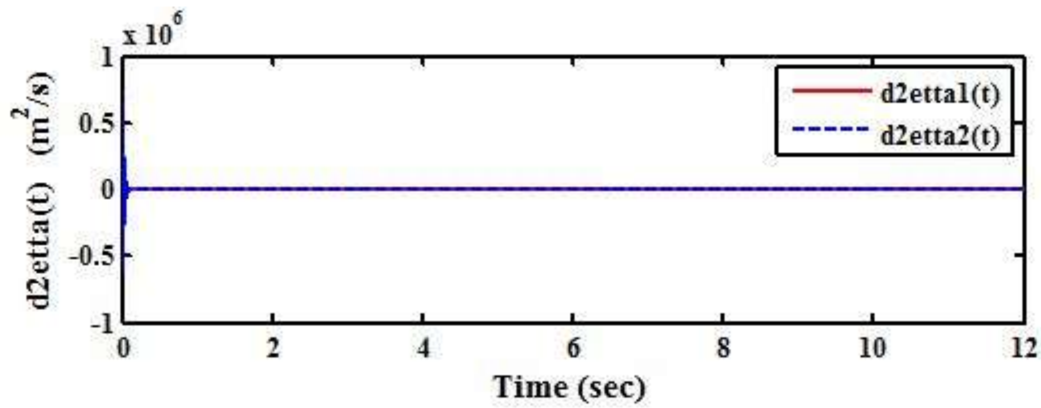

Figure.11 Damped Modal response of $\ddot{\eta}$

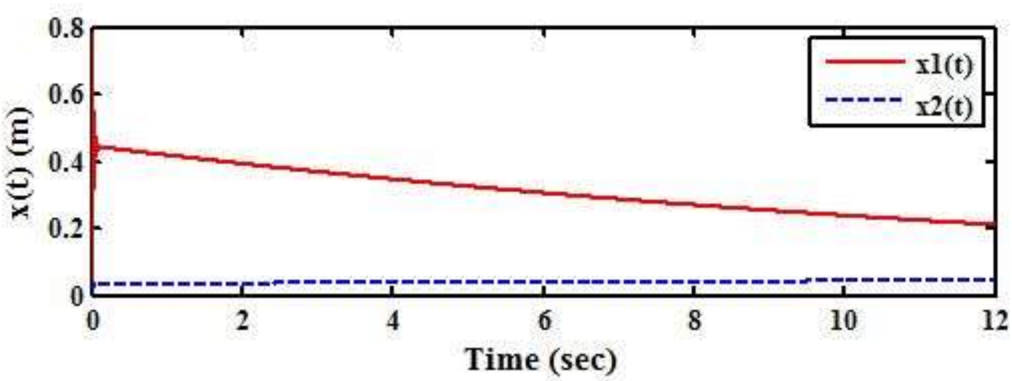

Figure.12. Damped System response of $x(t)$

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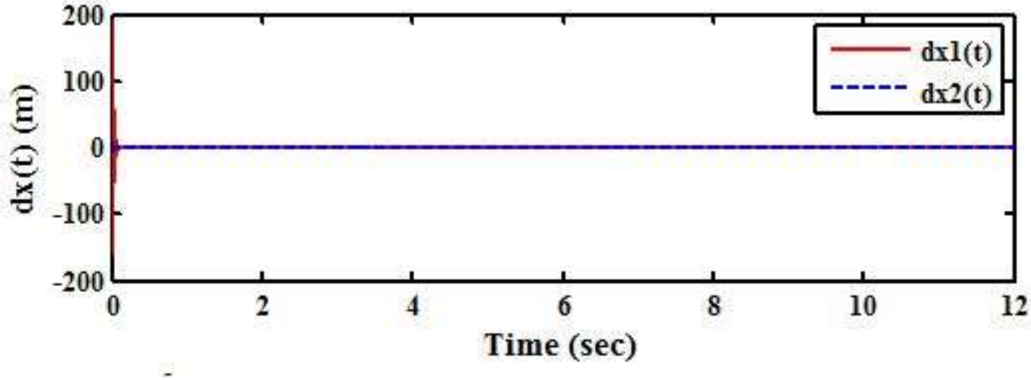

Figure .13. Damped System response of $\dot{x}(t)$

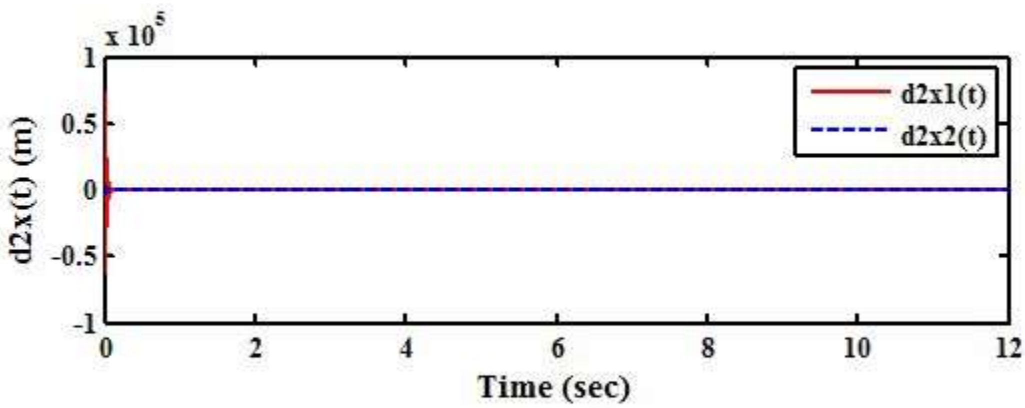

Figure.14. Damped System response of $\ddot{x}(t)$

From figures 3 and 9, in modal responses of the amplitude of mass 2 is higher than mass 1 in both undamped and damped cases.In the case of accelerations for modal responses, in the initial stage the acceleration is high for mass 1 and after that it is collinear to each other.

CONCLUSIONS

This study discussed development of an implementable algorithm for assessing the performance of a two-degree of freedom Quarter car suspension model under free vibrations. The results were plotted for both no-damp and damped case to show the effectiveness of the implemented numerical method in solving the two-DOF suspension system. With respect to the suspension system, it is can be concluded that the driver does experience vibration during normal operations under passive suspension system may not be as much as with respect to the sprung mass or un-sprung mass, but significant to cause an effect on driver's health.

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