Ministry of Higher Education

& Scientific Research

University of Misan

College of Engineering

Simulation PID Control for an Active Quarter Car of the Suspension System

A project submitted in partial fulfillment of the requirements for the degree of Bachelor in Mechanical Engineering

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بسم الله الرحمن الرحيم

أَمَّنْ هُوَ قَانِتٌ آنَاءَ اللَّيْلِ سَاجِدًا وَقَائِمًا يَحْذَرُ

الْآخِرَةَ وَيَرْجُو رَحْمَةَ رَبِّهِ قُلْ هَلْ يَسْتَوِي الَّذِينَ

يَعْلَمُونَ وَالَّذِينَ لَا يَعْلَمُونَ إِنَّمَا يَتَذَكَّرُ أُولُو الْأَلْبَاب ﴾

صدق الله العلي العظيم

سورة الزمر: الاية[9]

ABSTRACT

The abstract discusses the limitations of conventional passive suspension systems, which struggle to balance comfort and control. Active suspension systems, in contrast, offer better comfort, control, and stability during cornering and braking, especially in rough terrain. The paper reviews the modeling, simulation, and control of active suspension systems using MATLAB/Simulink. A proportional-integral-derivative (PID) controller is used to optimize system performance, and the results of the active system are compared to those of a passive suspension system.

Chapter One

Introduction

Chapter One

Introduction

1.1Suspensions of the Car

Suspension systems are the most important part of the car affecting the ride comfort of passengers and road holding capacity of the car, which is essential for the safety and stability by isolating the body from road shocks and vibrations which usually encounter from ground, for instance, in traveling on a rough surface, or crossing over an obstacle. Prolonged exposures to vibrations cause some problems, such as pain for the passengers. To alleviate these problems, momentary loads from ground should be absorbed and damped out. Automotive suspension systems are intended to absorb and decrease the shocks and vibrations transferred from the ground to the passengers as well as the car body **[1]**.

There are three types of car suspension systems classified as passive system, semi active system and active system. Passive system which had the capacity to store energy passing through a spring and to waste it by a damper. The parameters were generally fixed, being chosen to achieve a certain level of compromise between road holding, load carrying and comfort. The semi-active system is better than the passive suspension because the damping fluid. These fluids have different damping coefficient that vary with the change in operational conditions, this change in damping coefficient achieves by controlling the electromagnetic valves inside the absorbers**[2].** An active suspensions one including an actuator that can supply active force, which is regulated by a control algorithm using data from sensors attached to the body car. An active suspension employs force actuators which in turn creates the desired force in suspension system. The actuator is protected in parallel with spring and shock absorbed as a result in high-quality suspension construct it was significant to lessen the disturbance to the yield purpose. Several engineers and researchers in the automotive industry field devoted particular attention to discuss the problem of vehicle suspension control in order to develop the characteristics of both ride comfort and driving safety. The intelligent suspension system includes control strategies, sensor technology and actuator **[3]**. The suspension system of the car shown in figure (1.1).

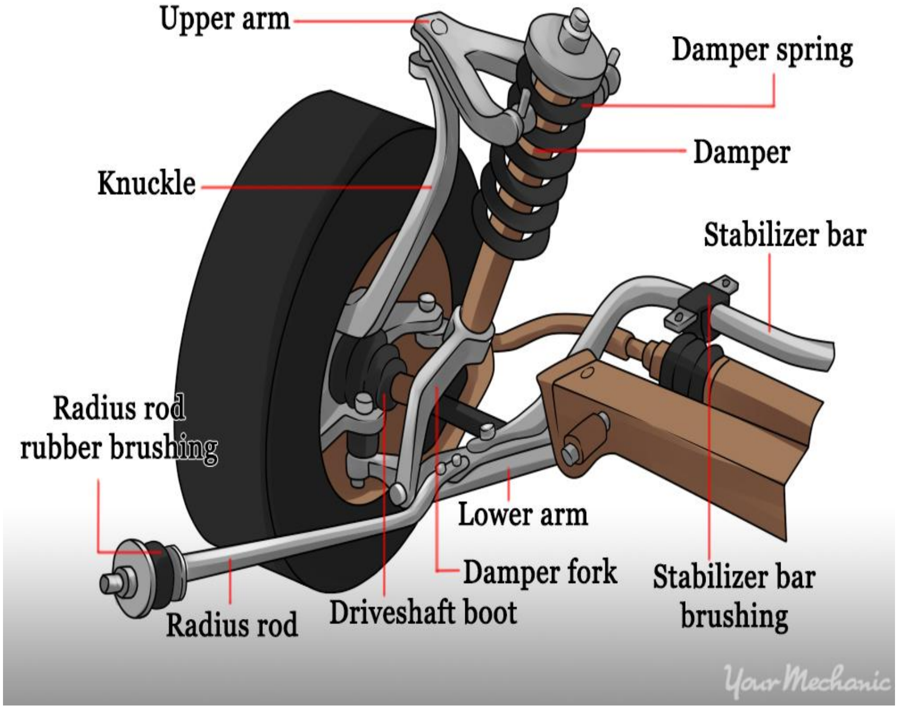

Figure (1.1): The Suspension System of the car

1.2 Improvement of Vibration Isolation Performance of Suspension System with Uncertain Parameters

The reason to design a car suspension system with independent control of stiffness, damping and ride height comes from the disturbance complicated in differing requirements of ride and handling. the suspension system capable to control of stiffness, damping and ride height to improved car response . The application to improved car response requires the stiffness change to be immediate and no change in ride-height during stiffness change. In the suspension system the weights, the stiffness coefficient and damper cannot be considered constants therefore design a controller can be tuning the verify of these parameters gain and analyze the effects of variable stiffness to isolated the response car and ride comfort. The vibrations that occur in suspension from external disturbance are almost harmful and dangerous to system structure and human health or activity **[4]** . Therefore, vibration isolation systems have been extensively studied in order to improve ride comfort for both the passengers and the driver. It is well known that the stiffness of an isolation system has a substantial influence on isolation effectiveness. An isolation system with a high stiffness will be more subject to vibration than a low stiffness isolation system. However, reducing of system stiffness will lead to decreasing of load support capacity of the isolation system**.[5].[6].** The main goal of the active suspension system used in a car is reducing the vibration .so the controller is applied to a car suspension. ensures the vibration reduction lead to good ride comfort despite the parametric uncertainties while keeping suspension travel and tire deflection in acceptable limits**[7].**

1.3 Controller System

The mathematical equation of the car suspension system has been simulated for active suspensions system of quarter car . The benefit from use the control to reduce the vibration of active suspension systems. The

1.3.1 Proportional - Integral - Derivative (PID) Controller

PID controllers are widely used in industrial plants because it is simple and robust. Industrial processes are subjected to variation in parameters and parameter perturbations, which when significant makes the system unstable**[8].**

Designing and tuning a proportional-integral-derivative (PID) controller appears to be conceptually intuitive, but can be hard in practice, if multiple (and often conflicting) objectives such as short transient and high stability are to be achieved. Usually, initial designs obtained by all means need to be adjusted repeatedly through computer simulations until the closed-loop system performs or compromises as desired. This stimulates the development of "intelligent" tools that can assist engineers to achieve the best overall PID control for the entire operating envelope. This development has further led to the incorporation of some advanced tuning algorithms into PID hardware modules**[9].**Figure(1.3) shown PID control**[10].**

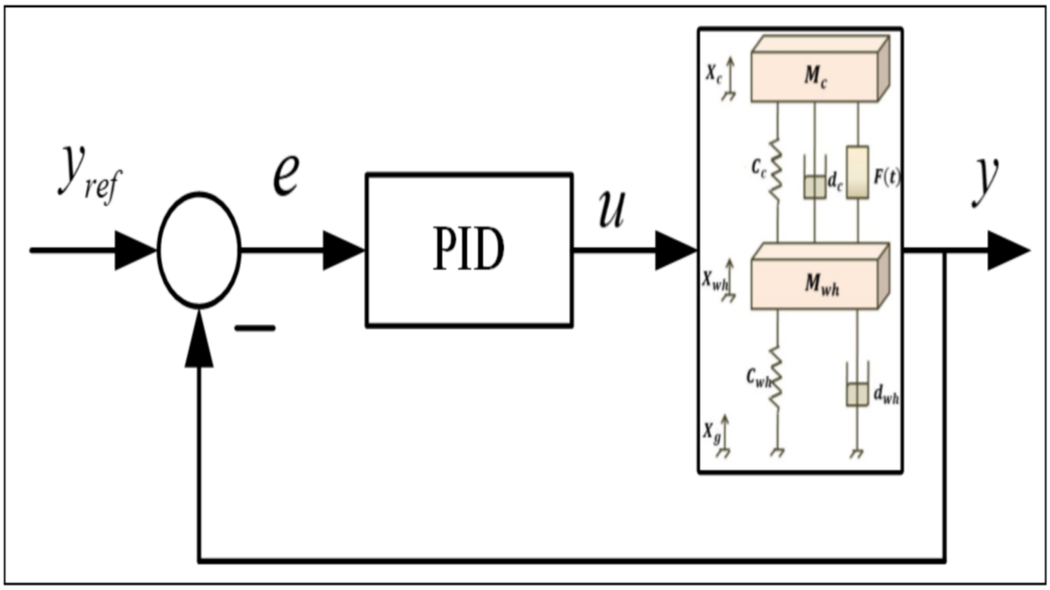

Figure (1.3) : PID Control Diagram**[10]**

Chapter Two

Literature Review

Chapter Two

Literature Review

This chapter includes several researches discussing controls the suspension of the car. Active PID control studied and comparison the result with uncertain stiffness.

2.1 PID Control Applied on Active Suspension System

There are many organized study to enhance the driving of the car by applying the suitable controller such as (PID) control and discussed the result on the efficiency and stability of the road vehicle. The Matlab\Simulink had been utilized to obtain the data for the model system and the controller used:

Yagiz, N., & Hacioglu, [11] discussed the control design is presented for the control of a car active suspension system. A seven degrees of freedom (DoF), non-linear full vehicle model is used. control is preferred in this study since it offers a systematic procedure for the construction of the functions and related feedback control laws, which agreement the stability of the system with a very successful improvement in ride comfort. Additionally, some implementation issues concerning the controller design are addressed to improve the applicability and performance of the controller. Thereafter, the efficiency of the controller is evaluated both in time and frequency domains. For the time domain analysis, different road conditions are considered in order to reveal the performance of the controller in detail. Finally, some concluding remarks extensive time responses with different road conditions and the frequency responses have indicated that the designed controller performed efficiently resulting in improved ride comfort of the passengers.

Agharkakli et al.[12] studied the mathematical model for the passive and active suspensions systems for quarter car model. Current automobile suspension systems using passive components only by utilizing spring and damping coefficient with fixed rates. Vehicle suspensions systems typically rated by its ability to provide good road handling and improve passenger comfort. Passive suspensions only offer compromise between these two conflicting criteria. Active suspension poses the ability to reduce the traditional design as a compromise between handling and comfort by directly controlling the suspensions force actuators **.** The methodology was developed to design an active suspension for a passenger car by designing a controller, which improves performance of the system with respect to design goals compared to passive suspension system

Tiwari, P., & Mishra, [13] presented the Suspension systems are designed to maintain vehicle stability by reducing the effects of dynamic loads while providing a comfortable ride through the reduction of impulse forces from terrain features. Suspension system is mechanism that physically separates the car body from the car wheel. The primary function of a suspension system is to minimize acceleration inputs to a vehicle. Ride comfort is one of the most critical factors to evaluate the vehicle performance. There are generally two procedures to evaluate the ride comfort of a vehicle, i.e. computer simulation and road experiment. Computer simulation method is based on the mathematical model of the vehicle vibration. Simulation programs can be effectively used to extrapolate the experiment results over the range of test conditions Suspension systems originally came to use in horse-drawn carriages. The suspension system is of three types: Passive suspension, Semi-Active suspension and Active suspension. conclusions are made in this paper present in next sub section. The dynamic model of car had been constructed through bond graph technique.The model of controller-suspension contact dynamics had been constructed by using bond graph technique. Minimum wheel deflection for better handling performance and minimum vertical car body velocity for ride comfort have been achieved in terms of low overshoot and settling time which is complimented by simulation results**.**

Hang et al . [14] In this paper, a parallel structure of PID control systems is proposed. It is associated with a new tuning method which, based on gain margin and phase margin determines the parameters of the PID controller. In comparison with conventional PID controllers, the proposed PID controller shows higher control gains when system states are away from equilibrium and, at the same time, retains a lower of control signals. Consequently, better control performance is achieved. With the proposed formula, the weighting factors of a logic controller can be systematically selected according to the plant under control The validity of the proposed PID controller and gain and phase-margin-based tuning formula is appeared through theoretical analysis and experiment. Both theoretical and experimental results show that the PID controller has the nonlinear properties of higher control gains when the system is away from its steady states; and lower control when set-point changes occur. As a result, these nonlinear properties provide the PID control system with a superior performance over the conventional PID control system.

Woo et al.[15] studied the typical PID control model, suggested original controller system, i.e. PID controller a arranged to expand additional occurrence of situation and the steady state of the PID controller, a method had been developed for tuning the scaling gains of the PID with controller. The result of the simulation of controller with the model dynamic offered the best presentation for passing to steady state response.

Salem and Aly [**16]** studied the effort of logic to the manager of the damping road vehicle. The leader comfort is superior by means of the decrease the acceleration of the vehicle body during the disturbances since soft road and actual road roughness. Also described the model system and the control applied and debated the response data obtained for a domain the simulation road input. A conclusion makes a comparison between active suspensions with control and (Proportional Integration derivative (PID)) control had been viewed by utilizing MATLAB\Simulink. improved the Fuzzy control very effective and more stability of the one quarter car model

Pekgokgoz et al. [17] discussed logic has been used for tuning the active suspension the optimizing of membership by applying inherited algorithm process. The deflections of vehicle body and the structure of the control have been calculated and compared for PID control. The evaluation exhibits the efficiency and inconvenience of the logic controller (FLC) method. shown at the end of the research the logic better performance than (PID) for the body deflection and the efficiency of actuator force of the control

Changizi and Rouhani [18] discussed the theoretical result and the effected of the control (fuzzy control) when we used at active suspension showed the operative and can be employing in manufactured of the vehicle. Also appeared the new-found active suspension control system is planned to occur in cooperation ride relief and better handling. The fuzzy logic has been presented in result enhanced stability of the one-quarter vehicle model. The fuzzy logic control executes in addition and well result compare if the PID controller has been applied. Also the results shown that the Fuzzy logic was effective to the system than PID control

Moghadas et al.[19]studied the suspension system to separate car body from road disturbance for achieve comfort to the ride and keep constant road wheel contact for affording road investment. Also the research explained the purpose of fuzzy logic used on active suspension system. The benefit designed was proceeding when the body acceleration reduced to the body car during road turbulence from horizontal road and factual road force. In addition express the system used and controller applied the vehicle response results had been discussed acquired by a span simulations road input. Conclusion, disused the dynamic behavior for active suspension under fuzzy control and (Proportional Integration derivative, PID) control publicized using MATLAB\ Simulink.

Lan and Ni [20] studied -PID controller is industrial by using the logic control membership on the variation of the PID frame model The occurrence of the projected controller was established by show the difference on passive system under MATLAB/Simulink. The results of simulation designate that residential -PID controller effinciey of the car by dipping the acceleration and pitch angle appreciably.

Rosli et al.[21] described new control method applied to a vehicle suspension frame utilizing active Force Control (AFC) with Iterative Learning (IL) and (PID) control approach. Intended for damage the disturbances, and the furthest loop by means of a PID controller for the calculation of the required force. Quarter vehicle rig with programming simulation included the theoretical result. Evaluate the PID and passive elements. The vertical displacement, acceleration was without a doubt summary that means the comfort of passenger facet is enhanced when using control proposal.

Abdelhafez and Omara [22] offered the suspension system is active model offered to contain the vehicle vibration by utilizing (proportional derivative, PD), and positive position feedback controllers under time delay. The signal gives up of the controller was used electrical on magnet-rheological damper or Electrical-rheological damper that was closed parallel for passive mechanism to advance the suppression against the vibration. The signal of control electrical was formed by programming controller and the sensor location where are tied to the control. The special effects of element modification for the system and the controllers are to realize the best occurrence. Simulation grades appeared best operation.

Conker, C., & Baltacioglu, M. K. [21] studied the PID is provided to tune the optimum PID parameters by using a gain scheduling method. The tuning scheme is demonstrated by a decision process, which consists of fuzzification, knowledge and rule base, inference and defuzzification. Results of developed fuzzy proportional integral derivative (FPID), on-off, conventional PID control approach are discussed and compared. The presented result shows that self-adaptive PID controllers achieve better control performance than conventional control methods mentioned. The last but not the least, developed approach minimizes the expertise needed to apply pulse width modulation technique.

Wei Gao, et al.[22] studied a quarter-car model is used to investigate the vibration response of cars with uncertainty under random road input excitations. The sprung mass, unsprung mass, suspension damping, suspension stiffness, and tyre stiffness are considered as random variables. variation coefficient of the vehicle's natural frequencies and mode shapes are obtained by using the Monte Carlo simulation method. The computational expressions for the numerical characteristics of the mean square value of the vehicle's random response in the frequency domain are developed by means of the random variable's functional moment method. The influences of the randomness of the vehicle's parameters on the vehicle's dynamic response are investigated in detail using a practical example, and some useful conclusions are obtained.

Schiehlen, W., & Iroz [23] discussed the road vehicles are subject to random excitation by the unevenness of the road. For a dynamical analysis, vehicle models of the vertical vibrations as well as guide way models of the road unevenness are required. The fundamental dynamics of vehicle suspensions can be already modeled by a quarter car featuring the decoupling of the car body motion and the wheel motion. This suspension model is characterized by five design parameters where two of them, the shock absorber and the tire spring, are highly uncertain due to wear and poor maintenance. For the assessment of the vehicles performance three criteria have to be used: ride comfort, driving safety and suspension travel. These criteria depend on all the five design parameters resulting in a conflict or a pareto-optimal problem, respectively. In this paper, the uncertainties of the parameters are projected into a criteria space in order to support the decision to be made on the basis of a pareto-optimal problem. Simulations with uncertainties support the robust suspension design. It is shown that controlled suspension parameters remain uncertain due to the unpredictable decisions made by the driver.

Dai and Zhang [24] studied dynamic displacement and acceleration responses of cars with uncertain parameters under random road input excitations are investigated by using a quarter-car model. Based on the theory of random vibration, the vehicle’s random displacement and acceleration responses are developed in time domain and frequency domain. The sprung mass, unsprung mass, suspension damping, suspension and tire stiffness are considered as random variables Ride comfort, working space and road holding are very important indices to assess the performance of vehicles and vehicle suspension systems. Ride comfort is dependent on the acceleration of vehicle body or sprung mass. Working space is the relative displacement between the wheel and vehicle body (suspension travel) investigate the random vibration of cars with uncertainty. The vehicle’s parameters are considered as random variables. The random displacement and acceleration responses of vehicles are developed

2.2 Chapter Summary

Literature reviews of the studies the mathematical model for the passive and active suspensions systems for quarter car model.car suspension systems using passive components only by employ spring and damping coefficient with fixed coefficient and with uncertain coefficient .The attitude was industrial to design an active suspension for a passenger car by designing a controller, which improves performance of the system with respect to design goals compared to passive suspension system.

active (PID) suspension systems applied to improve the response of the car . Theoretical results for components of the model used by utilizing the Matlab simulation.

Chapter Three

Mathematical Modeling of Quarter Car Suspension

Chapter Three

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In this chapter will be offered the mathematical modeling of the passive suspension system and active suspension system of the quarter car with all elements.. The results will be obtained by using the software (MATLAB R2014b\SIMULINK).The step input is a road input used .

3.1 Mathematical Modeling

3.1.1 Mathematical Model for Passive Suspension Quarter car

Passive suspension systems which consist of spring and damper components have been traditionally utilized on different types of vehicles, such as motorcycles, passenger cars, trucks and even bikes. The suspension mathematical model is presented upon the equations of motion for 2- DOF suspension system, Good design of a passive suspension can to some extent optimize ride and stability, but cannot eliminate this compromise. It is consisting of a sprung mass referring to the part of the car that is supported by spring and damper and unsprung mass which refers to the mass of wheel assembly. A simple representation of the tire is taken into account which is the tire equivalent stiffness neglecting the tire damping. The components of passive system are fixed as damper and sprung. Quarter car suspension is easy to understand, due to which it is usually used to study the car dynamics . Equations of sprung mass and un sprung mass solving this systems of equations is difficult so we can use Matlab\ Simulink software. solving the system and its verification will be done by the method: write the equations in Matlab using Simulink library blocks. The diagram of passive suspension system contains main elements will be shown in figure (3.1)

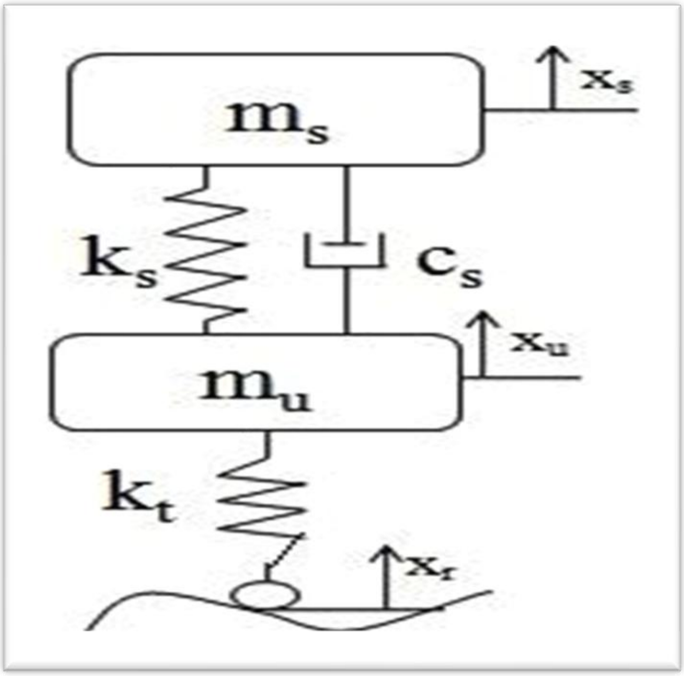


Figure (3.1): A Quarter Car of Passive Suspension System

where the:

(ms): is the mass of the car body (sprung mass)

(mu) is the mass of the tiers (unsprung mass).

(ks) Is stiffness of the spring

(kt) is stiffness of tire

(cs) is the coefficient of the damper,

(xs) is the displacement of body (sprung mass),

(xu) is the wheel displacement (unsprung mass),

($\ddot{x}s$) is the acceleration of body mass,

($\ddot{x}u$) is the acceleration of the wheel,

($\dot{x}s$) is the velocity of the body

The Newton second law has been applied on the parameters. Note that it is assumed that the tire is firmly held in contact with the road surface specifically. no slipping occurs and that only vertical motion is considered. From figure (3.1) the linearity equations of the car body and the wheel are derived in this fashion **[25**].

Equation of the sprung mass is derived as :

$$\ddot{X}s = [-Ks(Xs - Xu) - Cs(\dot{X}s - \dot{X}u)/Ms \quad (3.1)$$

Equation of unsprung mass is derived as:

$$\ddot{X}u = [Ks(Xs - Xu) + Cs\left(\dot{X}s - \dot{X}u\right) - Kt(Xs - Xr)]/Mu \quad (3.2)$$

3.1.2 Mathematical Model of Quarter Car for Active Suspension

The basic idea in active control of suspension is to use an active element (the actuator) to apply a desired force between the car body and wheel axle. This desired force is computed by the car control unit to achieve certain performance objectives under external disturbances, such as passenger's comfort under road imperfections The active suspension is characterized by the actuator placed in parallel with the damper and the spring. Because the actuator connects the unsprung mass to the body, it can control both the wheel hop motion as well as the body motion. Thus, the active suspension now can improve both the ride comfort and road handling capability **[25].** By means of this organization the substantial achievements in car reaction will be carried out where so the suspension systems are turn into controllable systems. The actuator stores extra force to the suspension system sequentially to reduce the vibrations caused by rough road, **.** A quarter car model is most common, mostly studied and very effective to study the dynamic performance of one quarter of car parts and a single suspension under various road profiles. The quarter car model is simple to design and provides results in quick time using simulation work compared to complicated full car model. The designed active quarter car model with integrated controller in primary suspension is shown in figure (3.2) . .

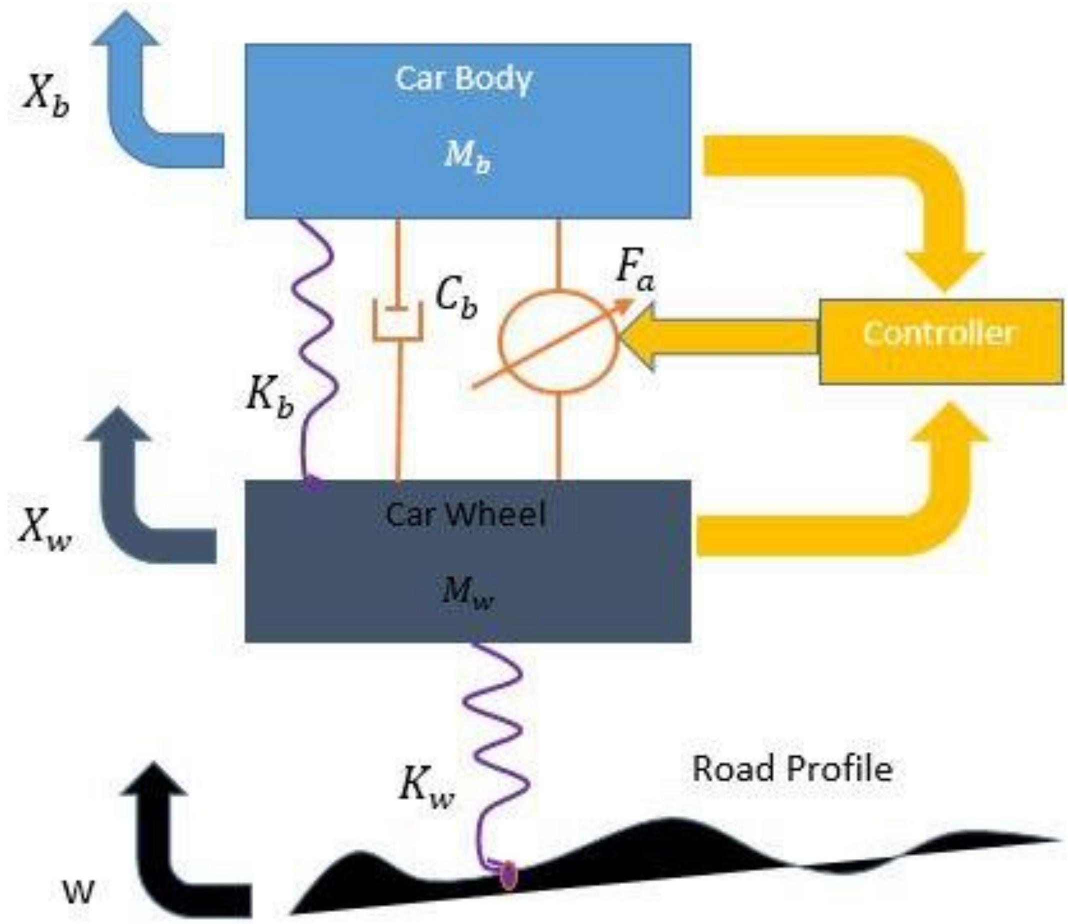


Figure (3.2): Active Suspension System of Quartet Car

Where-

- (ms) is the Effective vehicle body mass(kg)
- (ks) is the spring stiffness (N/m)
- (cs) is the damper coefficient (N/m)
- (Fa) forse actuator (N)
- (mu) Effective mass for wheel and axle (Kg)
- kt (N/m) Stiffness of tire

$-xs\ displacement\ of\ sprung\ mass$

-xu displacement of unsprung mass

by means of the Newton's second law of motion of quarter car of active suspension system. The equation of the sprung mass and unsprung mass for are derived as:

Equation for Ms :(sprung mass)

$$\ddot{Xs} = \frac{Cs(\dot{Xu}-\dot{Xs})+Ks(Xu-Xs)}{Ms} \tag{3.3}$$

Equation for Mu (unsprung mass)

$$\ddot{Xu} = \frac{\boldsymbol{Fa+Cs(\dot{Xu}-\dot{Xs})+ks(Xu-Xs)+Ct(\dot{Xu}-\dot{Xr})+kt(Xu-Xr)}}{\boldsymbol{-Mu}} \tag{3.4}$$

3.1.3 Block Diagram (simulation) for Quarter Vehicle of Passive Suspension System

The simulation of vertical movement of quarter car body with one and two DOF by exercising software programming Matlab/SIMULINK. The differential equations (3.1) and (3.2) are solved. The element of passive suspension as(;ms,mu, ks,cs,kt) are completely depend parameter of them with step input equal 0.1m is used . The block diagram of this simulation is shown in figure (3.3)

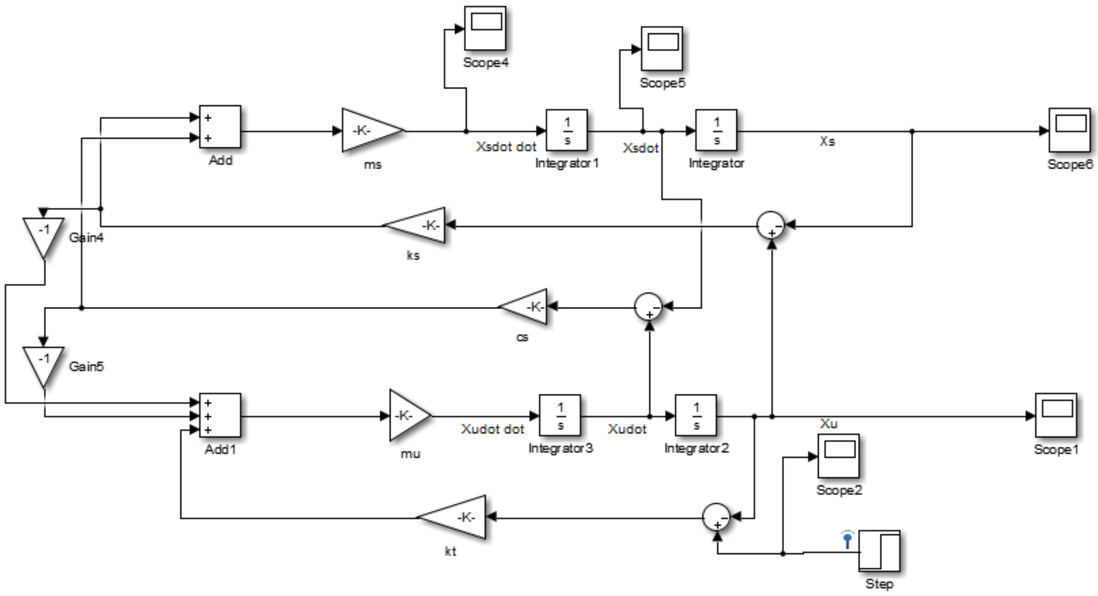


Figure (3.3): Block Diagram of Quarter Vehicle Passive Suspension

3.1.4 Block Diagram for Quarter Car of Active Suspension

In order to realize optimizes between ride equality and road handling, and between soft and firm ride and can control car manner changes due to corner, acceleration and braking, the controlled system should have the ability of adapting for changing road environments. As mentioned, this ability represents the main advantage for active system The simulation of vertical movement of quarter car body with one and two DOF by exercising software programming Matlab/SIMULINK. The differential equations (3.3) and (3.4) are solved. The block diagram of this simulation active suspension system is shown in figure (3.4)

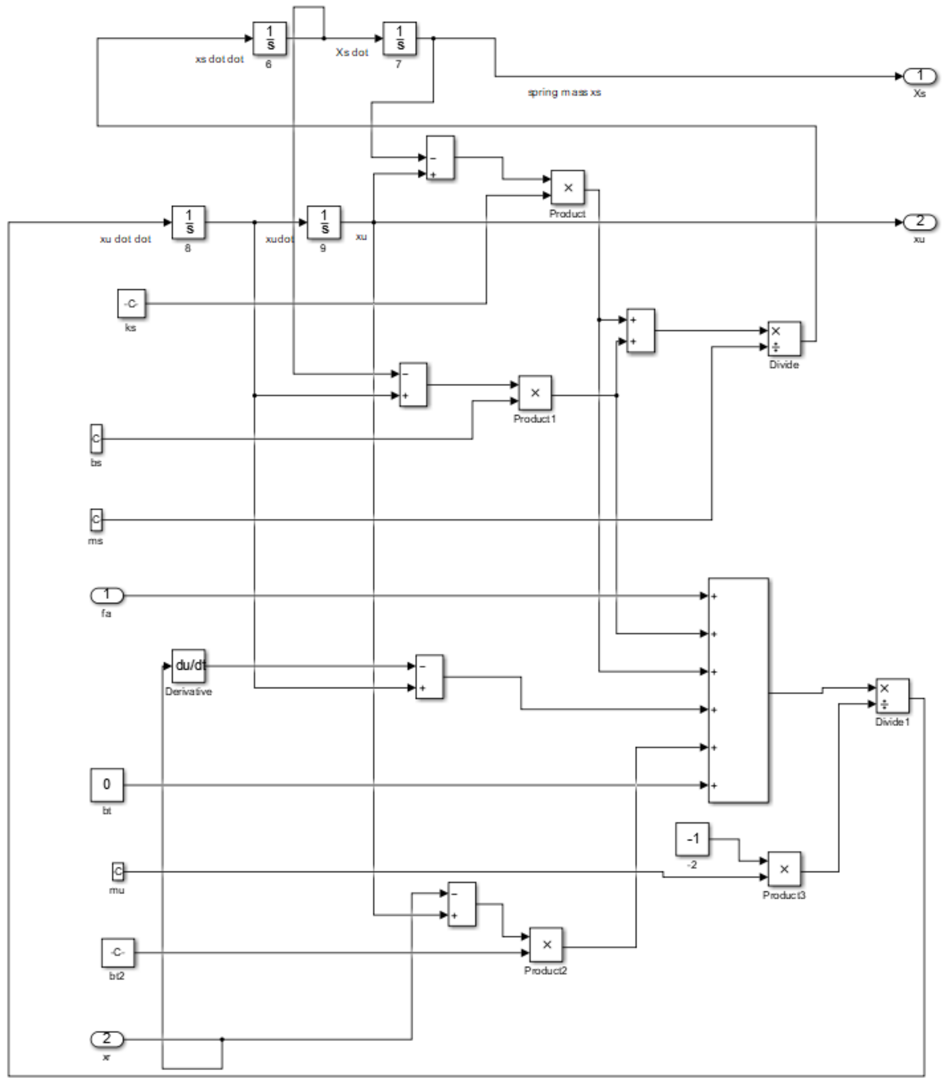


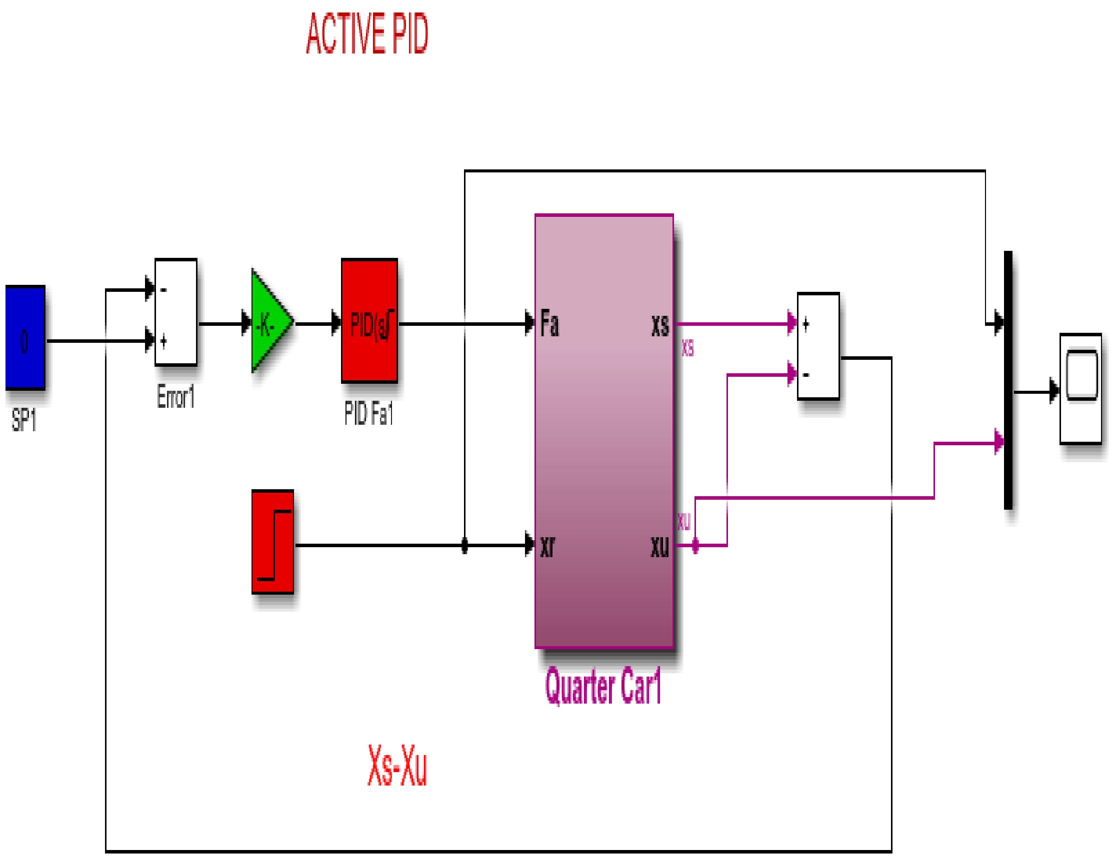
Figure (3.4): Simulink of the PID Controlled System

This block diagram has been structured as a sub system model the output from it is the feedback (xs-xu) which was with desired point (0) is presented the error of the system as the equation:

$$e(t) = \text{desired point} - \text{feedback}$$

3.2 Design the active Control of Quarter Car Suspension System

The PID controller is a standard control loop feedback mechanism significantly utilized in industrial control systems, which estimates an error signal as the difference between calculated process signal(xs-xu) and a preferred set point. Design of PID Controller using optimization method. shown in figure (3.5).



Figure(3.5): Simulink of Active PID control of Quarter Car Suspension System

Chapter Four

Results and Discussion

Chapter Four

Results and Discussion

In this chapter analyzed the vertical response of the passive suspension system of quarter car. The stiffness changing in magnitudes to review the isolation the car from external disturbance. The active suspension so analyzed by applying active PID control which stimulated and optimized the gains (kp,ki,kd) with varying the stiffness that accrued the spring suspension car subjected.

4.1 The Dynamic Response of a Quarter –car Suspension System

4.1.1 Response of Passive Suspension System

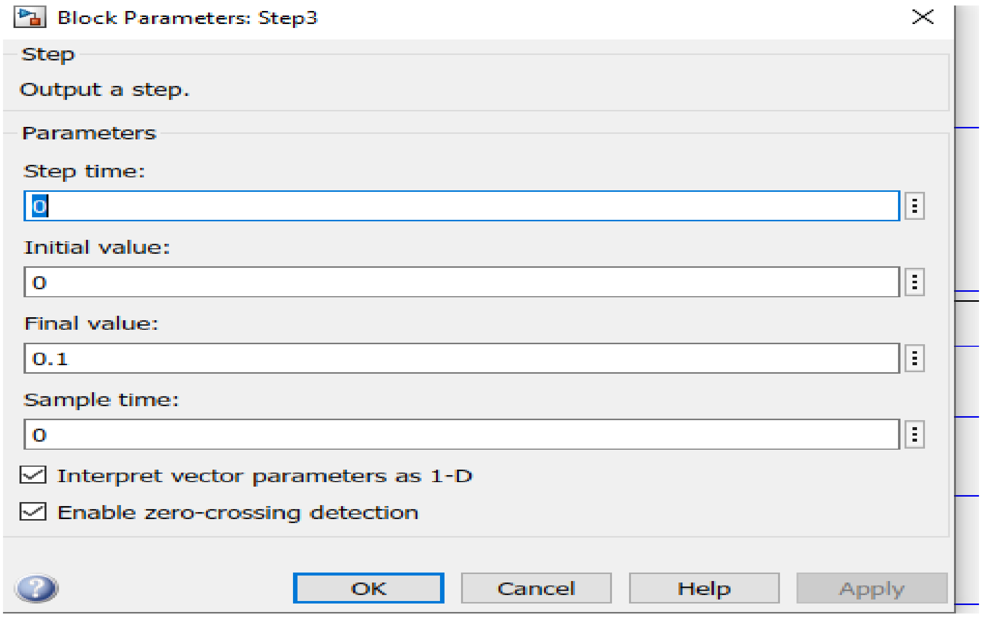
Most of car companies use passive suspension system according to its simple design with low cost in manufacturing and maintenance **.**The passive suspension is still developed in vehicle industry, The parameters of passive suspension springs and dampers are fixed, the main parameters as, ms (sprungmass), mu (unsprungmass), ks (stiffness of the spring), kt (stiffness of the tire) and cs (coefficient of damper) simulated with MATLAB\simulation software .The model studied the response of vertical displacement . The tire has been replaced with its equivalent stiffness and tire damping is neglected. The suspension, tire and passenger seat are modeled by linear springs in parallel with dampers. Because the actuator connects the unsprung mass the displacement of un sprung mass simulated in order to analyzed the improvement response. Table (4.1) show the parameters value on simulation of the quarter car.

Numb	The parameters	Symbol	Quantity	Unit
1	Sprung mass	m_s	250	Kg
2	Unsprung mass	m_u	50	Kg
3	Spring stiffness	k_s	16800	N/m
4	Damping coefficient	c_s	1000	N.s/m
5	wheel stiffness	k_t	190000	N/m

Table (4.1): The Parameters of the Quarter Car

Displacement

The results response of the passive suspension system of unsprung mass are obtained from the simulation equation (3.2).figure (4.1) shown the properties of the road inpute subjected to the car .figure (4.2) shown the vertical response of passive suspension



Figure(4.1): Road Input properties

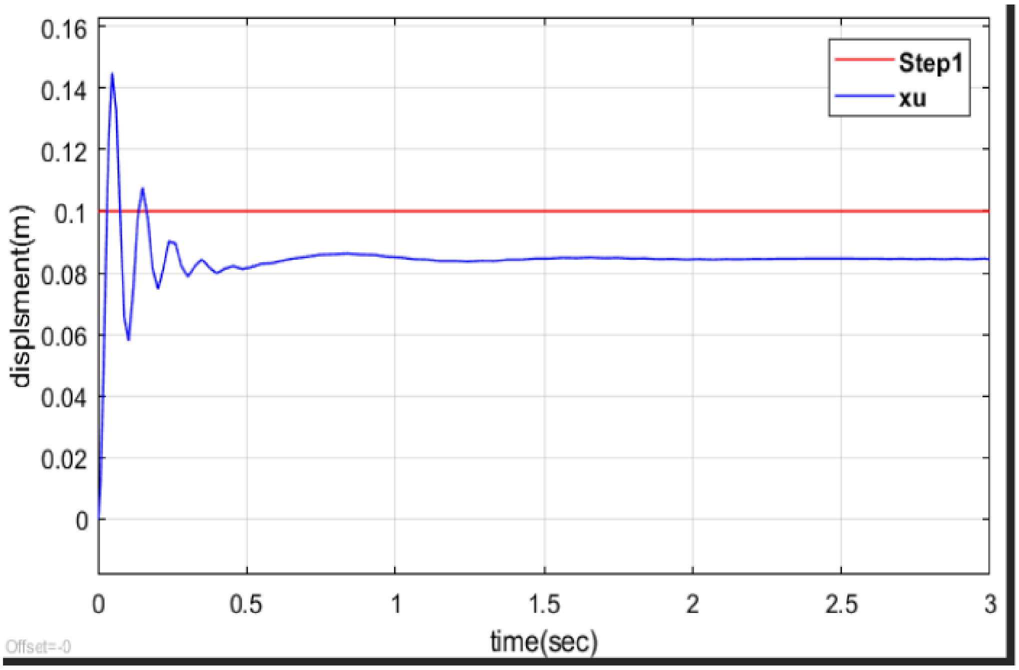


Figure (4.2):Vertical Response of quarter car Passive system.

The displacement response of unsprung mass quarter car passive suspension system had taken in the simulation of results by using Matlab\simulink to analyzed the vibration isolated . In the passive system there was no external force so control and isolate the car in a clear way that cannot be achieved

4.1.1.1 Influence the uncertain stiffness to the dynamic response of passive suspension system

The effect of varying value of stiffness on car dynamic response can be studied with passive system using helical spring .The full stiffness spring for the quarter car (ks=16800) changed in its value in order to investigate the influence of variations it on the car dynamic response. The spring is important part on suspension system store the energy if its subjected to any external disturbance or sudden impact as high stress at number of cycle a crack activated on its coil number the stiffness coefficient less a comparison is constructed between different magnitude of spring stiffness such as medium (M) and minimum (S) stiffness of main values. The aspect of improving car ride quality and passenger comfort can be achieved through isolated the vibration .A quarter car suspension model is analyzed for step input with variable stiffness. to studied the effected on the response behavior according to the rang of vibration and comfort ride which enhancement by reducing external disturbances and isolating the car while changing its value stiffness of spring on the passive suspension system. .figure(4.3)-(4.4) shown the vertical response with medium and less(small) the main value of spring stiffness passive suspension system of the quarter car.

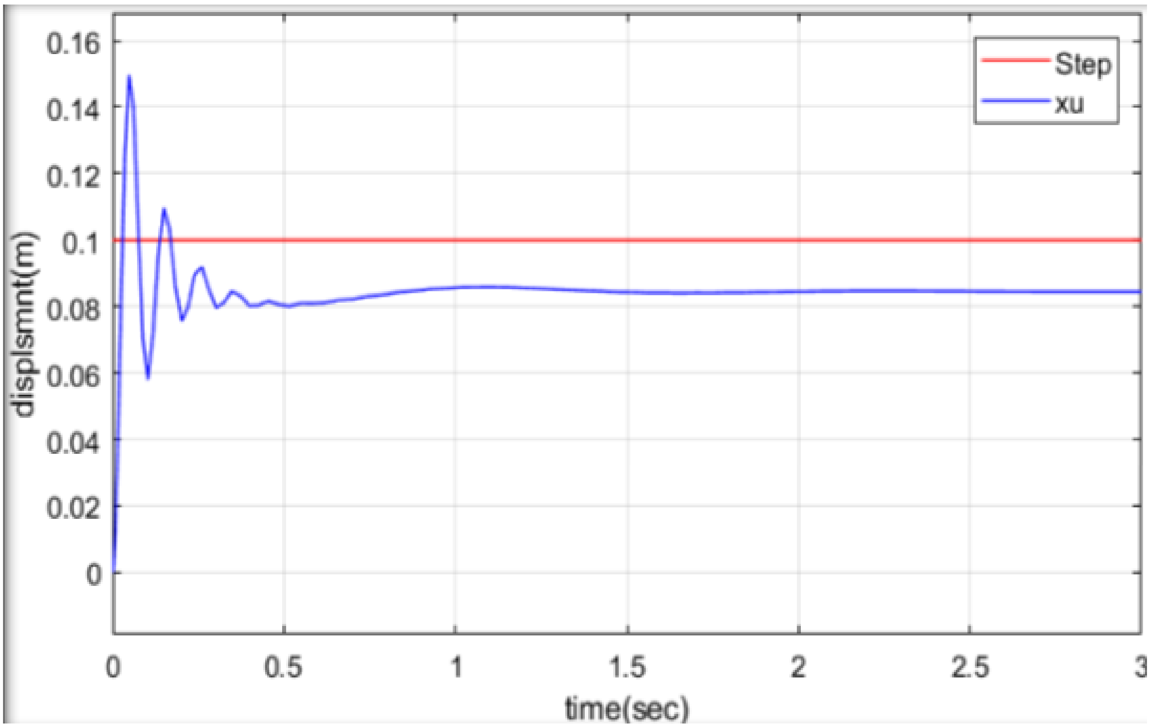


Figure (4.3): vertical Response displacement of Quarter car with Passive (50%stiffness)

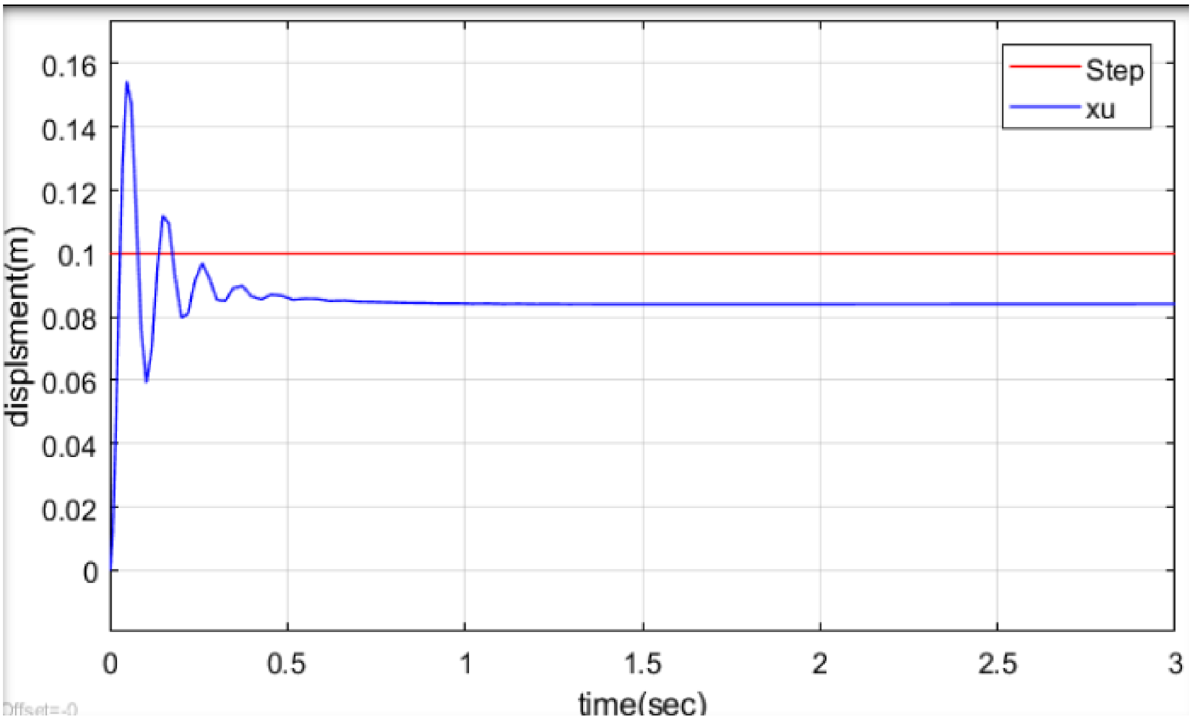


Figure (4.4): Response displacement of Quarter car with Passive (minimum stiffness)

In the figure (4.5) the passive suspension system with uncertain stiffness to improved the response of quarter car subjected to variable stiffness according to road condition.

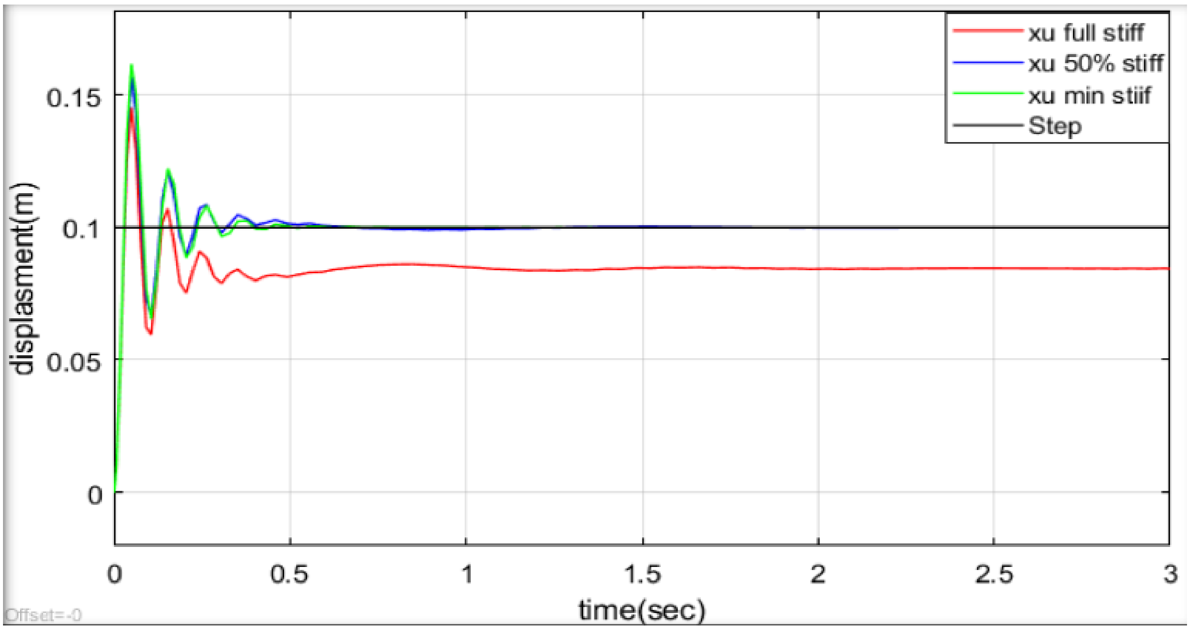


Figure (4.5): vertical Response displacement of passive system with uncertain stiffness

4.1.1.2 Analysis of simulation Results of passive system with Uncertain Stiffness

A good suspension system should provide a comfortable ride and good handling within a reasonable range of deflection. Though a passive suspension system can perform this task, its parameters are generally fixed, being chosen to achieve a certain level of the compromise between comfort and handling The passenger comfort, tire grip and suspension deflection are respectively taken as the vibration suppression indices to design of a good suspension system is concerned with isolation of the disturbances from the car’s body. A conventional passive suspension needs to be both ‘‘soft’’ to insulate against road disturbances and ‘‘hard’’ to insulate against load disturbances. Therefore, suspension design is a compromise between these two goals. The primary object is to improve ride comfort for a passenger car, first by optimizing the values of stiffness and isolation the vibration of a passive suspension system. The results that are obtained from quarter car simulation model of the car passive suspension can be analyzed using specification of isolation the response displacement. The loads acting on the suspension system may be on-changed and the stiffness of spring suspension may be subjected to a crack so it's changed. full stiffness magnitude used , 50% stiffness and minimum stiffness of main value of spring suspension passive system are used. The result and conclusion that are obtained from the previous analysis are :Agreeable design of a passive suspension be able to some scope optimize ride and stability, but cannot remove disturbance of car suspension . Passive system with uncertain spring stiffness are summarized as: for a certain stiffness of the car suspension it can be noticed that vibration increased if the stiffness decreased because the spring It cannot take its function to absorb energy and external disturbances from the road due to a crack in its parts.

4.1.2 The Response of the Active Suspension (PID control)

car manufacturing industries are required high speed demands with controlled dynamic behavior of operation car. One way of achieving the best ride comfort, safety and road holding abilities at varying the conditions of car are application of active suspension system .Active suspension can successfully control the vertical vibration of automotive body parts such as wheels as well as suspension stroke with in an acceptable level. The tremendous progressive growth in active suspension system technology lead to the development and availability of latest mechatronic based devices such as sensors,. Active suspension system can successfully control its own working according to various road and vehicle load conditions. It can deliver best performance in a wide range of occurrence compared to passive and semi-active suspension systems**.** The(proportional-integral-derivative) (PID) control provides a generic and efficient solution to control problems. The wide application of PID control has stimulated and development to get the best response of the car. The desired closed loop dynamics can be obtained by adjusting the three parameters kp, ki and kd. often iteratively with "tuning" and without specific knowledge of a plant mode.

The results of the active PID suspension are shown in figure (4.6).The vertical response of quarter car are obtained from the simulation equation(3.3) and (3.4) under PID control

Displacement

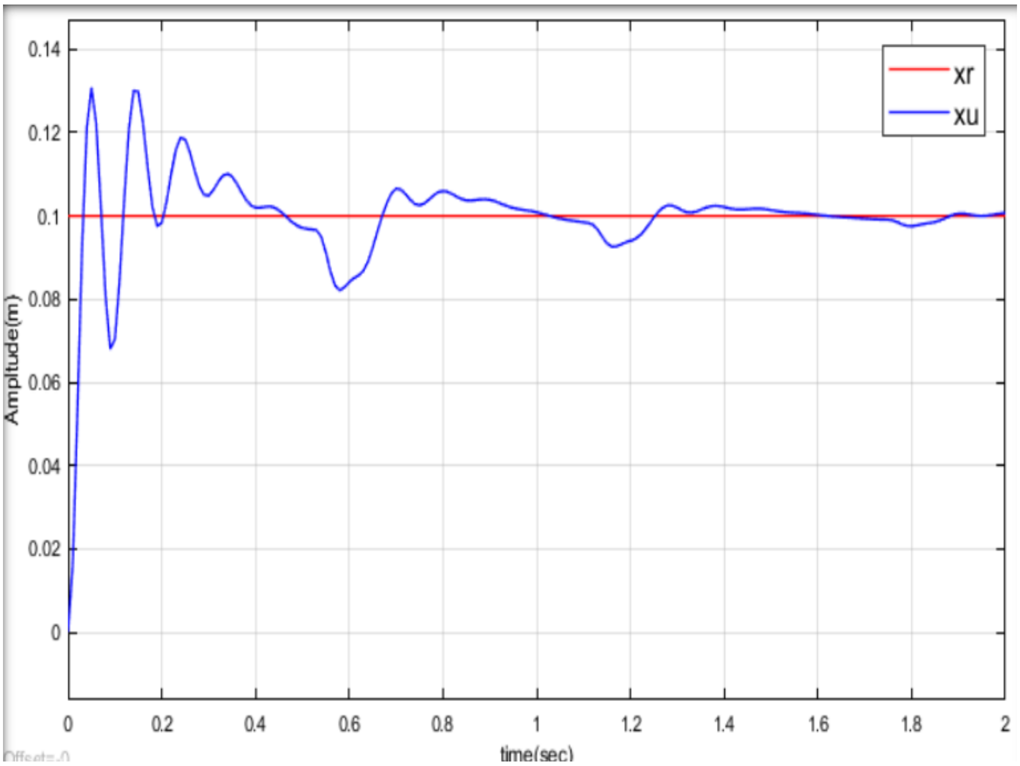


Figure (4.6):Vertical Response of Active PID system

In the active suspension system the control gain used to improve the response of the car with full stiffness of spring coefficient as shown in the table(4.2) .

kp	ki	Kd
24.4	3.5	0.0083

Table(4.2) PID parameter controller

4.1.2.1 Influence the uncertain stiffness to the dynamic response of active PID suspension system

A major purpose of any car suspension system is to isolate the body from roadway unevenness disturbances because of rough roads or at accrued a crack on the parts of the suspension system the suspension deflection may become large enough to cause high vibration , thus causing a severe degradation of isolation. Variable parameter suspensions are optimized to use the available suspension control to provide maximum isolation . step inputs at several intensity levels are applied to a quarter car model and the suspension parameters are optimized to find the best possible isolation under uncertain stiffness of main coefficient of spring .full stiffness of spring coefficient was studied to show the behavior of response as shown in figure(4.6). after that the spring subjected under a crack on active coil number so the stiffness coefficient less to (50%) of main value and the parameter of active PID control changed if this crack increased the failure point accrued and the stiffness be minimum value of main spring stiffness and the parameter of active PID control as well as changed according to this condition. figure(4.7)-(4.8) shown the response of vertical displacement of active PID control with medium and minimum(small) the main value of spring stiffness of the car.

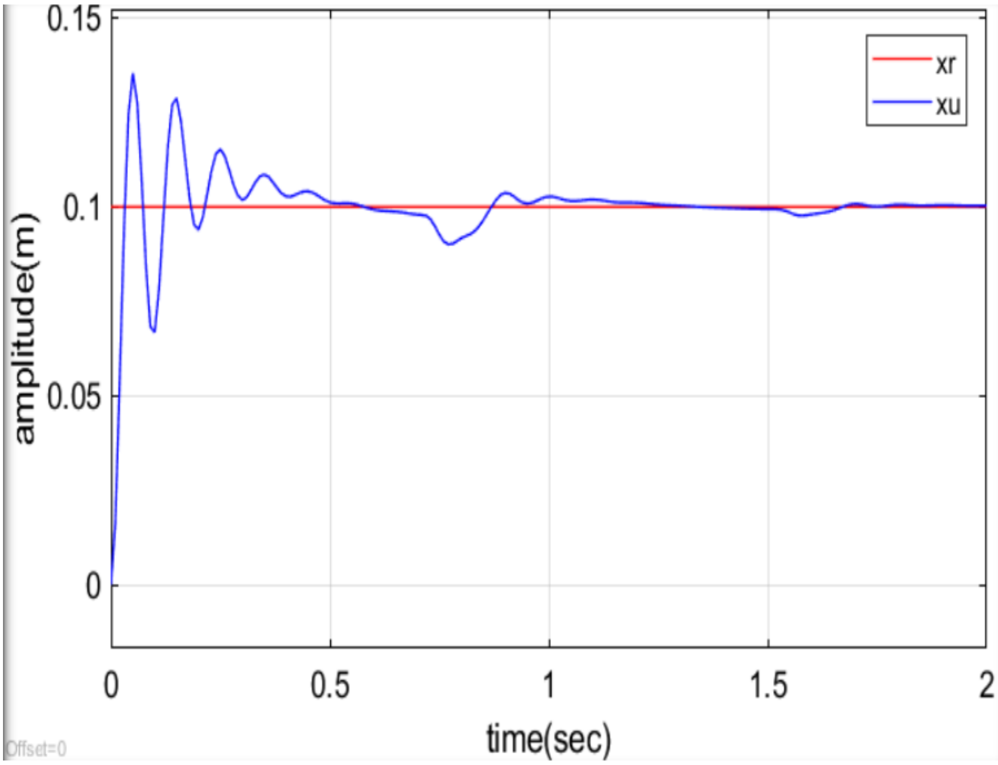


Figure (4.7): vertical Response displacement of Quarter car with active PID system (50%stiffness)

In the active PID suspension system the control gain used to improve the response of the car with 50% stiffness of spring coefficient as shown in the table(4.3).

kp	ki	Kd
16.5	1.5	0.0063

Table(4.3) PID parameter controller

Frome the figure (4.8) show that if the stiffness cofficcent decreased to(50%) of main value of suspension spring because the affected of a crack the vibration be more and the ride not comfort. but PID control applied on the active suspension enhancement the isolation of the system.

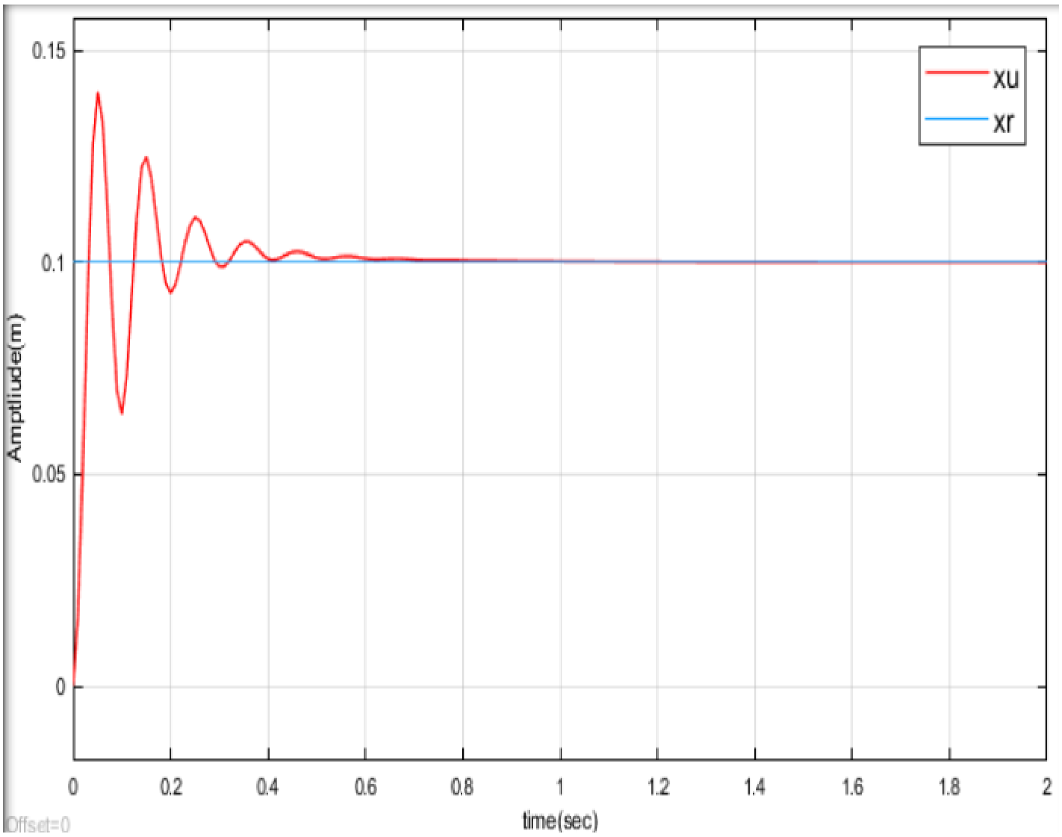


Figure (4.8): vertical Response displacement of Quarter car with active PID system (minimum stiffness)

In the active suspension system the control gain used to improve the response of the car with minimum stiffness of spring coefficient as shown in the table(4.4).

kp	ki	kd
0.1	0.2	0.005

Table(4.4) PID parameter controller

In the figure (4.9) the active PID control suspension system with uncertain stiffness to improved the response of quarter car subjected to variable parameter according to road condition.

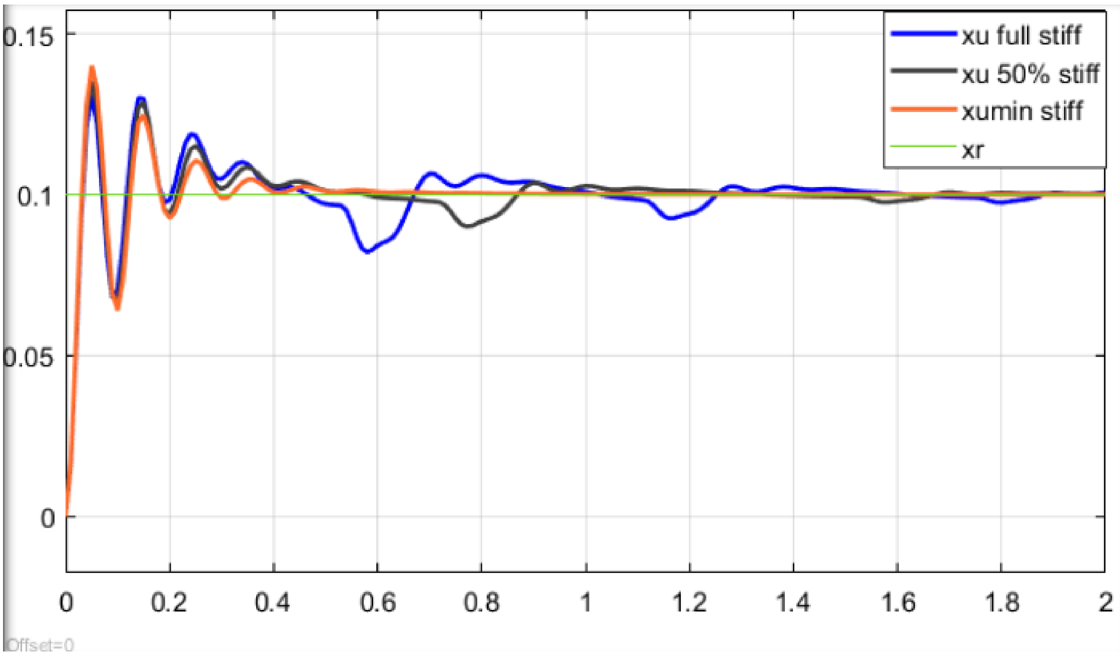


Figure (4.9): vertical Response displacement of active PID control with uncertain stiffness

4.1.2.2 Analysis of simulation Results of response active PID control with Uncertain Stiffness

Active systems will be thought of as, at least in part, replacing the springs and dampers of passive systems by actuators which act as force producers according to some control law. The actuators operate with force transducers providing inner loop feedback signals to their controllers and are imagined to road faithfully a force demand signal determined by the control law. Variable gain suspensions and tuning from control show good potential for suspension system improvement. Increased isolation is possible for greater ride comfort at the expense of larger force variations. Also, improved road holding is possible at the cost of ride comfort. With the inclusion of emergency sensing such as accursed a crack on the spring of suspension system the controller would be possible to obtain a high isolation on suspension.

So this type of suspension also has the possibility of manual control to suit driver preference, adaptive control that adjusts to the driving and roadway surface conditions and, the emergency system for maximum handling and safety.

4.2 A comparison between the Theoretical Result of the Dynamic Response

Passive System with Active PID control System (full stiffness)

Displacement

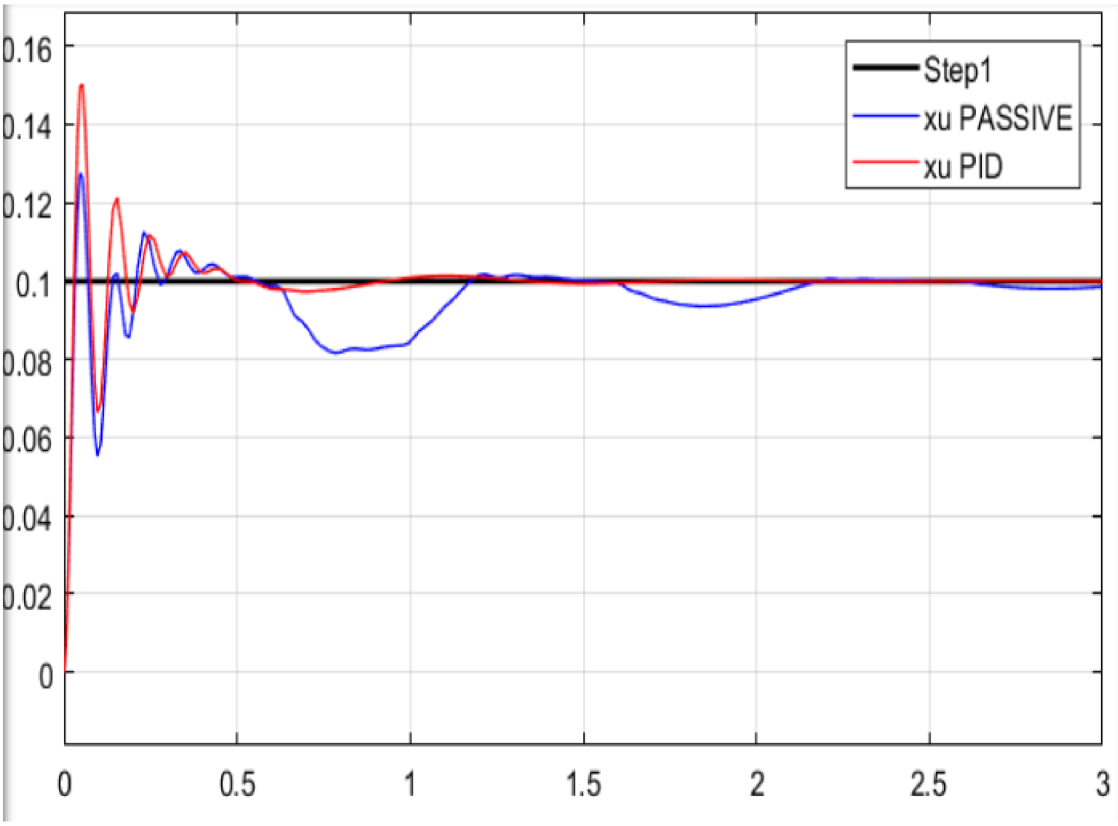
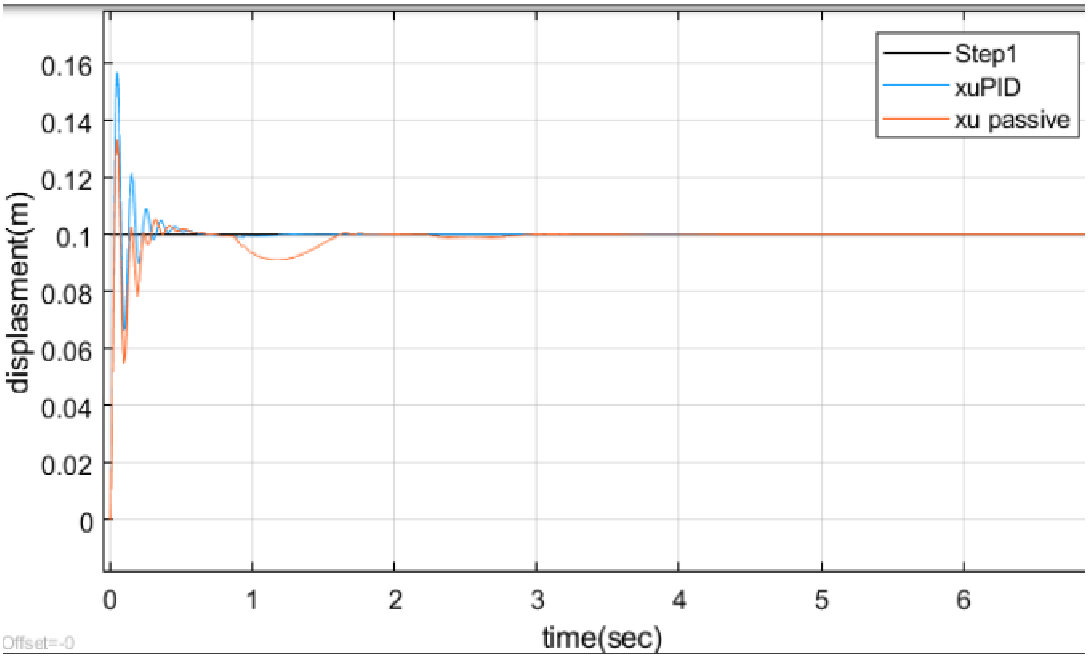


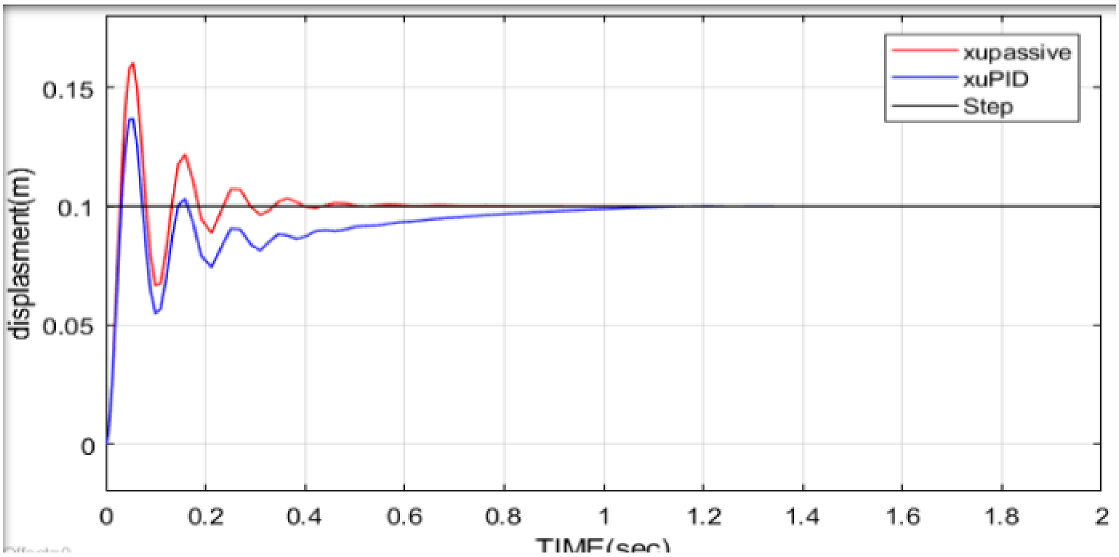
Figure (4.10): Response of Passive and Active PID Control

Passive System with Active PID control System (50% stiffness)



Figure(4.11):Response of Passive with Active PID control System (50% stiffness)

Passive System with Active PID control System (minimum stiffness)



Figure(4.12):Response of passive system with Active PID control System

(min stiffness)

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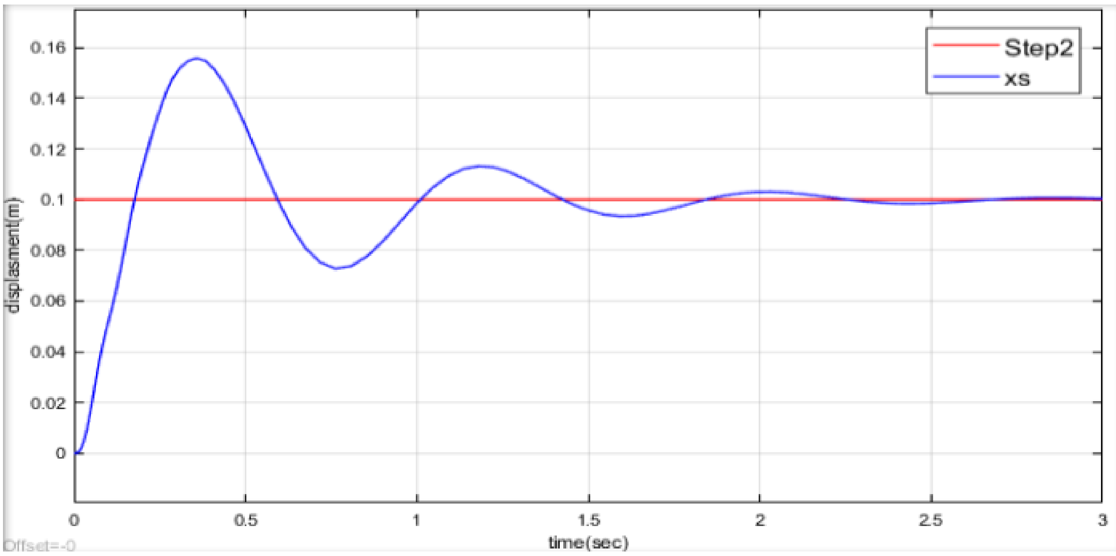

Figure (4.13): Response of sprung mass displacement with full stiffness

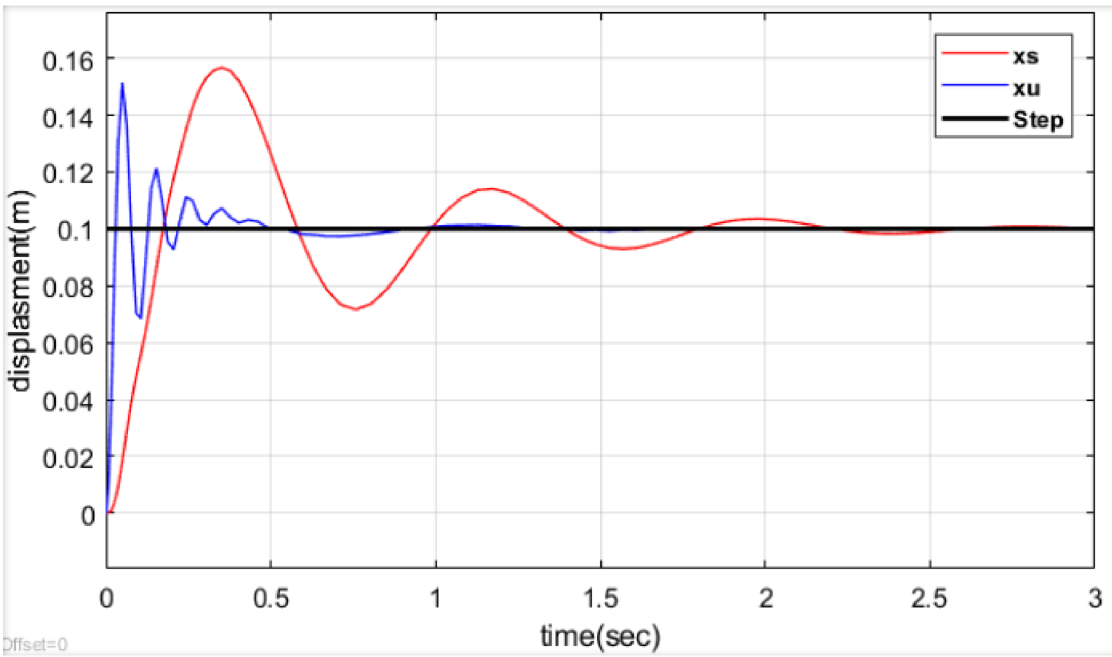

Figure (4.14): Response of sprung mass and un sprung mass displacement with full stiffness

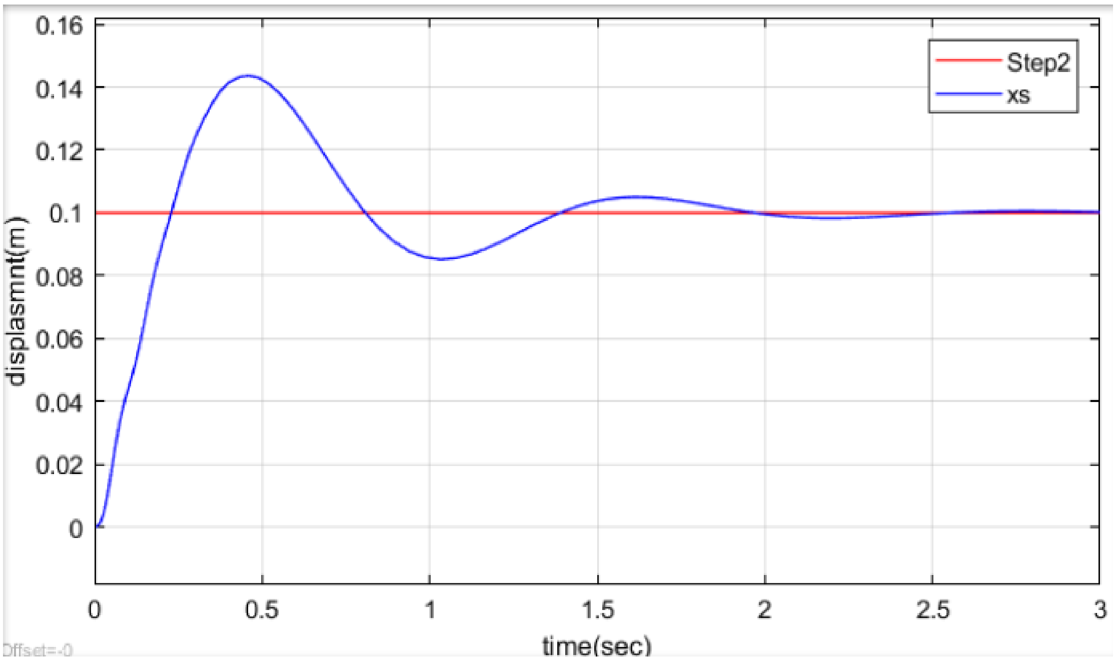

Figure (4.15): Response of sprung mass displacement with medium stiffness

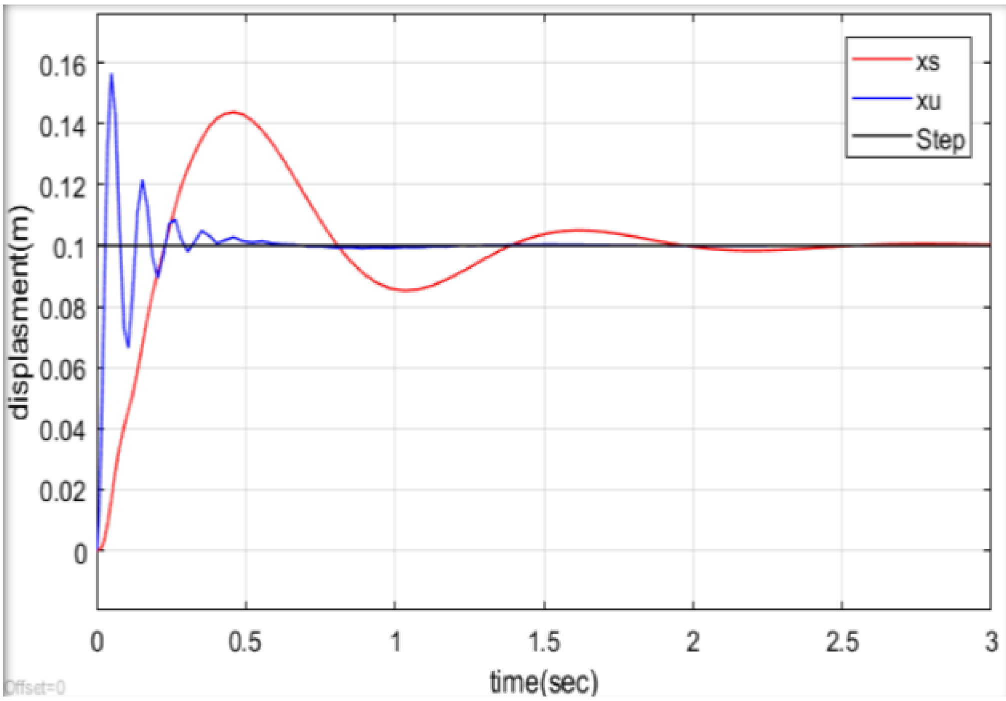

Figure (4.16): Response of sprung mass and un sprung mass displacement with uncertain stiffness

4.3 Influence of uncertain masses of Suspension System

investigates the problem of vibration isolation for car suspension systems, where parameter uncertainties such as the same car may carry various loads at different times . A constrained adaptive control technology is developed to not only stabilize the attitude of car but to control the variation of masses and external disturbances, Simulation results of different controllers(PID active control) are compared with passive suspension system under step input for uncontrolled and controlled cases are shown in figures(4.17)_(4.20).

Increased Masses with full stiffness

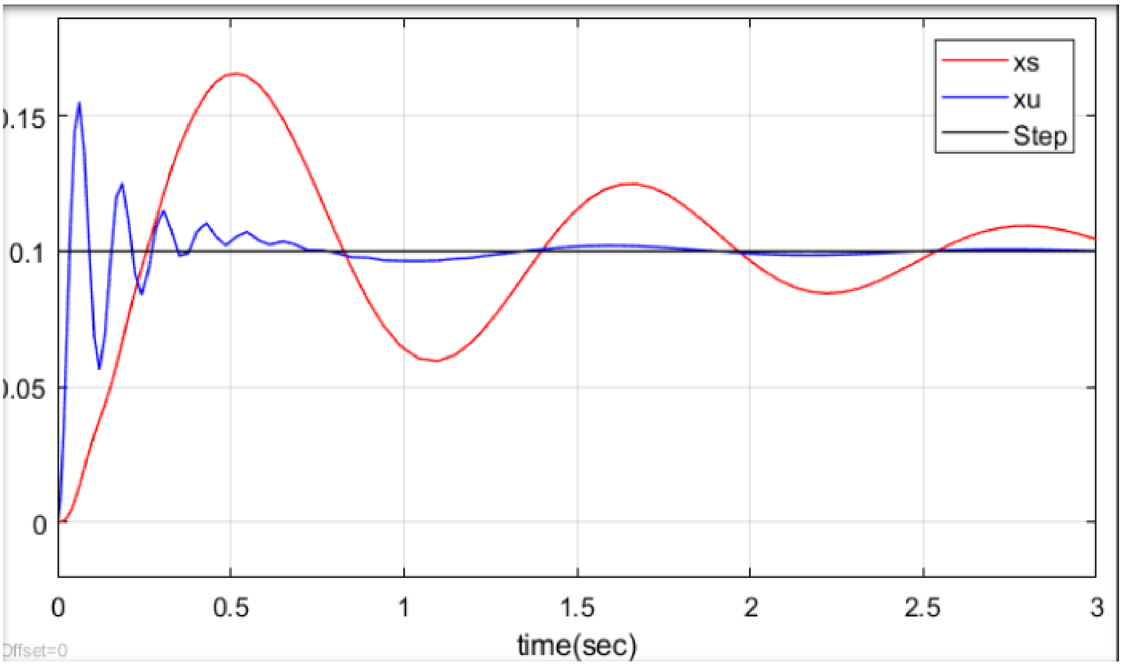

Figure (4.17): Response of sprung mass and un sprung mass displacement of Passive system with uncertain mass

Increased Masses with medium stiffness

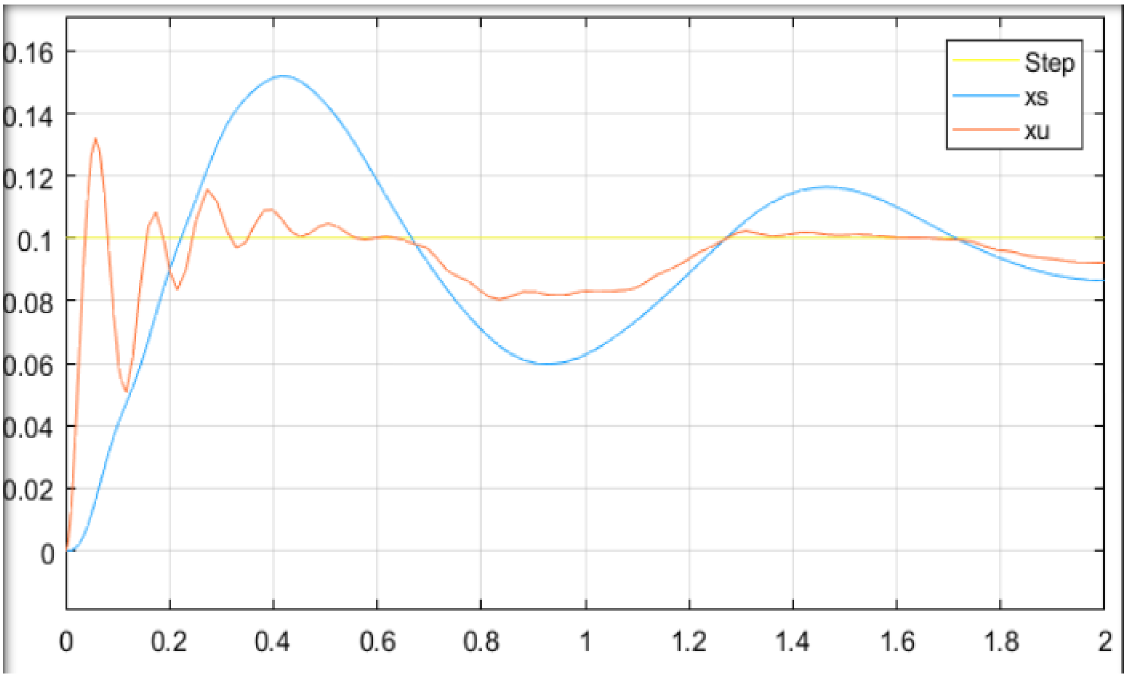

Figure (4.18): Response of sprung mass and un sprung mass displacement Passive system with uncertain mass

Influence the increasing to the response of active PID suspension system

Increased Masses with full stiffness

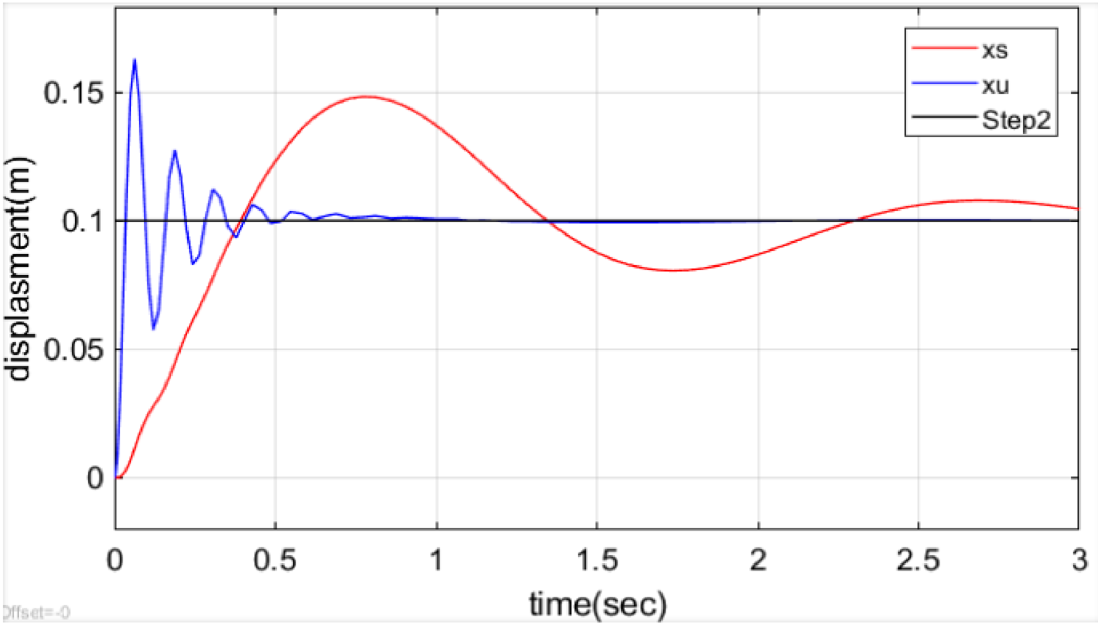

Figure (4.19): Response of sprung mass and un sprung mass displacement of PID control system with uncertain mass(full stiffness)

Increased Masses with medium stiffness

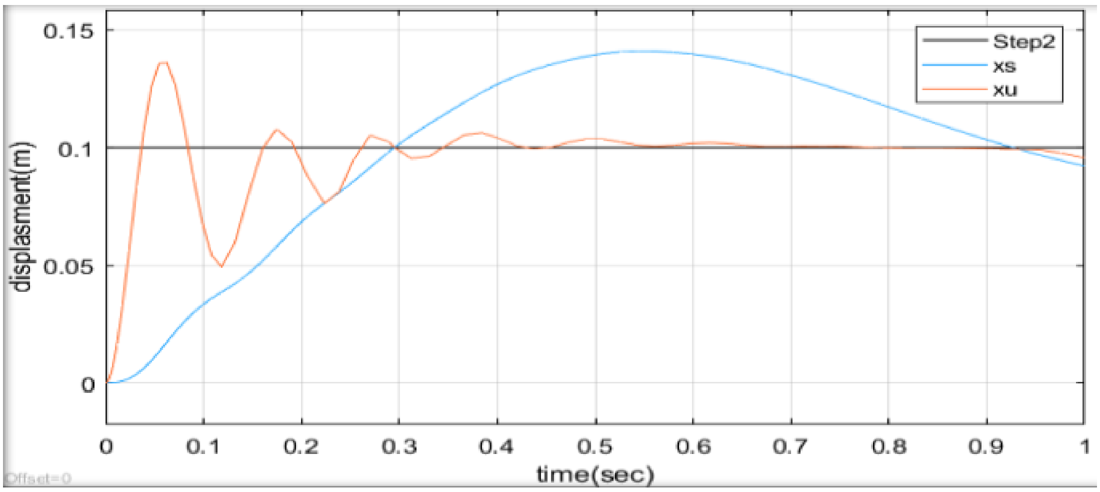

Figure (4.20): Response of sprung mass and un sprung mass displacement PID control system with uncertain mass(medium stiffness)

Chapter Five

Conclusions and Recommendations

Chapter Five

Conclusions and Recommendations

This chapter discussed the improve response of the passive system and active PID control with uncertain stiffness obtained theoretically by using Matlab /simulink **.**And the experimentally results of the test rig before and after stiffness of spring suspension verify comparison its effect at the stability of the car .

5.1 Theoretical Results Conclusions

The car suspension system differ depending on the manufacturer which ensures a wide range of models. Whichever solution is adopted to design, a suspension system has the primary role to ensuring the safety function. It is known that road unevenness produce oscillations of the car wheels which will transmitted to their axles. It becomes clear that the role of the suspension system witch connect the axles to the car body is to reduce as much vibrations and shocks occurring in the operation. This causes, the necessity to using a suspension of a better quality. A quality suspension must achieve a good behavior of the vehicle and a degree of comfort depending on the interaction with uneven road surface .When the car is requested by uneven road profile, it should not be too large oscillations, and if this occurs, they must be removed as quickly. The design of a vehicle suspension is an issue that requires a series of calculations based on the purpose and design a good control to minimize the vibration level of passenger seat and car body as much as possible. Passive system unable to isolated the vibration at the car because there was no external force .so active system with PID controller are widely used in the industrial applications and appropriate for car suspension control. Nevertheless, because of its characteristics to reduce the vibration by optimizing the parameters gain (kp,ki,kd) which changed according to road condition there for designing fuzzy logic controllers structure has two inputs and three output. The error (e) and change of the error (de) are used for producing a control output (kp.ki.kd) in order to reducing the vibration level of a car and being able to tuning the parameters gain of PID control. simulations are conducted by using the Simulink program in MATLAB for investigating the performance of the active controlled quarter-car model. The influence of verify the magnitude of stiffness spring suspension at passive system ,active PID contro analyzed these changing to improve the response of quarter car as following point:

1- Passive suspension system of quarter car increased of vibration if the stiffness spring decreased and there is not complete isolation in the response of the car.
2- Active PID control variation in the value of parameter gain(kp,ki,kd) when the stiffness difference at main value because of a crack occurred PID control improve the response and isolated the vibration.

5.2 Recommendations for Future the Work

There are a number of topics for future work and development related with the practical and simulation models which are designed and carried out in this thesis. These may include:

1. The effect of using the electromagnetic suspension systems based on Magneto- Rheological Damper to improve the performance of the car suspension with uncertain coefficient and provide the rid comfort of the passenger.
2. Study the influence of the spring car suspension with uncertain stiffness on the critical speed of the car with different external road inputs.
3. Improve the road response and ride passenger comfort by using the active controllable sliding mode controller for car suspension with uncertain stiffness.

4.The car simulating model with controllable active or semi active suspensions which are performed with LABVIEW software, this model may be used to study the mechanical problems in suspensions such as occurred uncertain stiffness of spring suspension system

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