Available online at www.sciencedirect.com
ScienceDirect
Procedia Engineering 97 (2014) 1274 – 1281
Procedia Engineering
www.elsevier.com/locate/procedia

12th GLOBAL CONGRESS ON MANUFACTURING AND MANAGEMENT, GCMM 2014

Modeling, Analysis and PID Controller Implementation on Double Wishbone Suspension Using SimMechanics and Simulink

Anand Tandel[a], A. R. Deshpande[b], S. P. Deshmukh[c], K. R. Jagtap[d,*]

[a,d] *Department of Mechanical Engineering, Sinhgad Institute of Technology and Science, Pune, 411041, India*
[b] *Department of Mechanical Engineering, Vishwakarma Institute of Information Technology, Pune, 411048, India*
[c] *Department of Mechanical Engineering, Sinhgad Academy of Engineering, Pune, 411048, India*

Abstract

This paper presents modeling of quarter car double wishbone suspension prepared by using the toolbox SimMechanics and Simulink of MATLAB software. SimMechanics uses the physical model of suspension, whereas Simulink uses the mathematical model of quarter car suspension. PID controller is then implemented on both the models to minimize the vertical body acceleration. The analysis is then carried out for various combinations of suspension parameters like spring stiffness and damping coefficient. The results for body acceleration are obtained and results of analysis of both the models are compared.

Selection and peer-review under responsibility of the Organizing Committee of GCMM 2014

Keyword: Double wishbone suspension; PID controller; Body acceleration; Parametric analysis; Active quarter car suspension

1. Introduction

The purpose of suspension system in the vehicle is to provide the ride comfort to the passenger as well as improving the road handling of vehicle. The suspension system is a mechanism that physically separates the car body from the wheel. The main function of suspension system is to minimize the vertical acceleration of the car body that is transmitted to the passengers, which will contribute to ride comfort. It must also keep the tyres in contact with the road, which helps in handling of vehicle.

Daniel Fischer et al [1] derived the mathematical models for suspensions with variable dampers and springs as well as active components for fault detection and diagnosis of the damper by combining parameter estimation and parity equation methods. Ikbal Eski et al. [2] designed the neural network based robust control system to control vibration of vehicle's suspensions for full suspension system and compared with the performance of standard PID controller. G.Priyandoko et al. [3] applied hybrid control technique to a vehicle active suspension system of a quarter car model using skyhook and adaptive neuro active force control. Ervin Alvarez-Sanchez [4] presented a robust control scheme for a quarter-car suspension system under a road disturbance profile and presented a linear mathematical model in order to design a sliding mode controller that allows avoid the induced road variations over the car body.

* Corresponding author.Tel.: +020-66831761; Fax: +020-66831710
E-mail address: krjagtapsits@sinhgad.edu

Selection and peer-review under responsibility of the Organizing Committee of GCMM 2014
doi:10.1016/j.proeng.2014.12.406

Mouleeswaran Senthil Kumar [5] developed an active suspension for the quarter car model of a passenger car to improve its performance by using a proportional integral derivative (PID) controller. P.E. Uys et al. [6] report on an investigation to determine the spring and damper settings that will ensure optimal ride comfort of an off-road vehicle, on different road profiles and at different speeds.Daniel A. Mantaras at el. [7] presented the three-dimensional model to study the kinematic behaviour of a McPherson-type steering suspension and determined the caster, camber and steer angle, which influence the handling of the vehicle in function of the operational factors of the system.

2. Mathematical Modeling

The study of suspension system has been performed by using various suspension models.In order to perform the simulation, a two degree of freedom quarter car model is used. Figure 1 Show the quarter car model for active suspension.

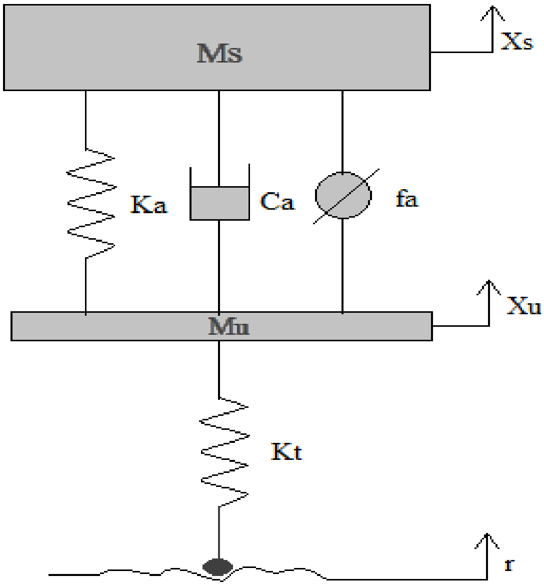

Fig. 1.Quarter car model for active suspension.

The equations of motion for the quarter car model are given by equation (1) and (2) and values of quarter car suspension parameters are shown in table 1;

$$Ms\,\ddot{Xs} + Ca(\dot{Xs} - \dot{Xu}) + Ka(\mathrm{Xs} - Xu) + \mathrm{fa} = 0 \quad (1)$$

$$Mw + Ca(\dot{Xu} - \dot{Xs}) + Ka(Xu - Xs) - \mathrm{Kt}(Xu - r) - \mathrm{fa} = 0 \quad (2)$$

Table 1. Quarter car model parameters.

Parameter	Value	Unit
Sprung Mass (Ms)	200	Kg
Unsprung Mass (Mu)	40	Kg
Tire Stiffness (Kt)	20000	N/m

3. Parametric Analysis

The parameters of wishbone suspension include stiffness of spring and damping coefficient of damper. These parameters affect the ride comfort of passengers and road handling of vehicle. The model of wishbone suspension is analyzed for different combinations of spring stiffness and damping coefficient to study the behaviour of suspension during the simulation. The vertical acceleration of car body for each of the combinations will be obtained by simulation. Table 2 shows the different combinations of stiffness and damping coefficient that will be applied to the suspension model during simulation.

Table. 2. Mechanical characteristics of spring and damper.

Sr No.	Spring Stiffness, Ka (N/m)	Damping Coefficient, Ca(N/m/s)
1	1500	30
		40
		50
		60
2	1600	30
		40
		50
		60
3	1700	30
		40
		50
		60
4	1800	30
		40
		50
		60

4. Modeling of quarter car wishbone suspension using SimMechanics

Wishbone suspension is modeled and assembled using SimMechanics 2nd generation toolbox in MATLAB software. The modules shown in fig 2 are used for modeling and assembly. Using body block from the body elements module, extrusion and revolution can be given to the geometry of the part, where the geometry is specified using the coordinates. Rigid transform block from the frames and transforms module is used to rigidly connect the different parts of the component. It specifies the position of one part with respect to other using two types of motion, translational and rotational. There are different joints in the joints module and depending on the degree of freedom required, appropriate joint is selected for connecting the two components during assembly of the model. The input to the model is given usingforces and torques module. The utility module contains the block Simulink-PS converter, which converts the Simulink signals to physical system signals. This converter is used toconnect the input block, which is thesignal builder block from source module available in Simulink. The output to the model is obtained using scope block from sink module of Simulink. The PS-Simulink converter is used to connect output block with the model. Fig 2 shows the SimMechanics model of active wishbone suspension prepared in SimMechanics 2nd generation in MATLAB software. The blocks indicate different components of suspension, like chassis, upper wishbone, lower wishbone, kingpin, damper, rim and tyre, which are connected to each other by means of constrained joints. The step input equivalent to bump height of 2 cm is given to the wheel using signal builder block. The spring stiffness and damping coefficient of spring and damper is varied to find out their effect on the acceleration of chassis. Active suspension uses a controller, which controls the actuator of suspension. It generates the force which helps in suppressing the body acceleration. PID controller is used in the active suspension model shown in figure 2. The PID block is available in simulink library. The Proportional, integral and derivative gain is tuned automatically by the block.

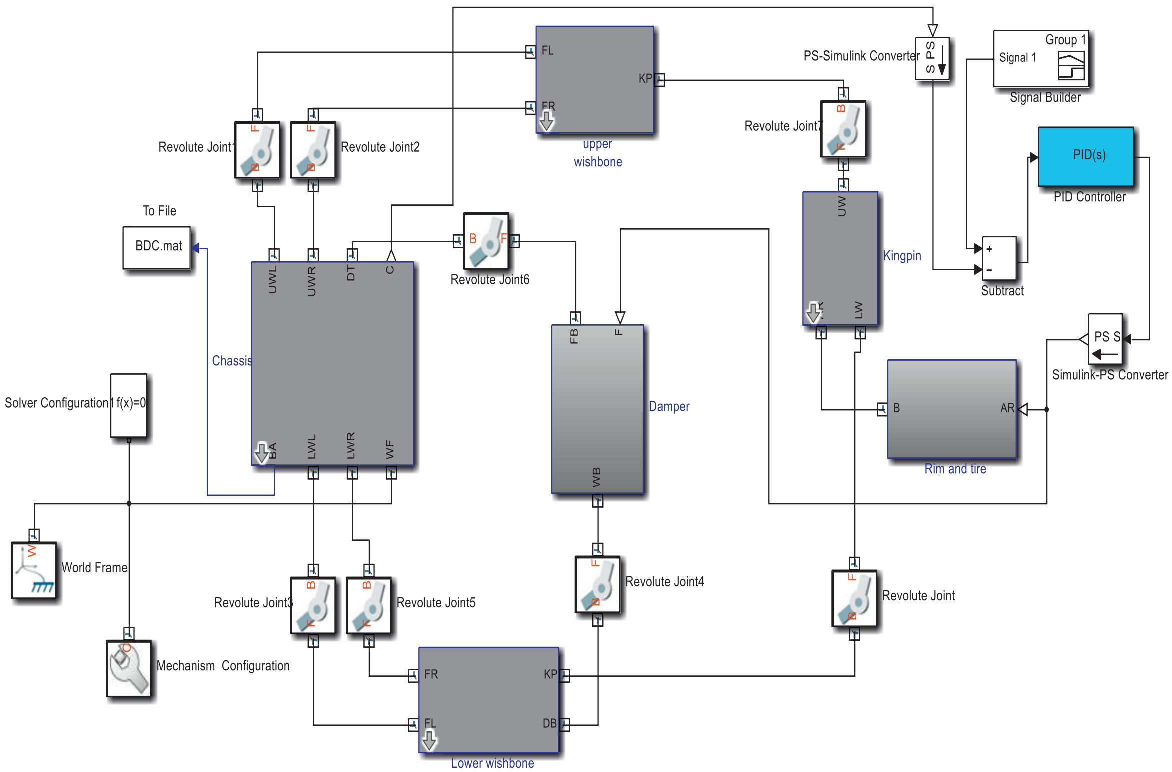

Fig. 2. SimMechanics model of active quarter car suspension.

4.1. PID Control Implementation

A proportional-integral-derivative (PID) controller is a generic control loopfeedback mechanism widely used in industrial control systems. A PID controller calculates an "error" value as the difference between a measuredprocess variableand a desiredset point. The controller attempts to minimize the error by adjusting the process control inputs.The PID controlleralgorithminvolves three separate constant parameters, and is accordingly sometimes calledthree-term control:theproportional, theintegralandderivativevalues, denotedP,I,andD.Simply put, these values can be interpreted in terms of time:Pdepends on thepresenterror,Ion the accumulation ofpasterrors, andDis a prediction offutureerrors, based on current rate of change.The weighted sum of these three actions is used to adjust the process via a control element such as the position of acontrol valve or adamper. In SimMechanics and Simulink toolbox, PID block is available in the library, which can be applied in the suspension model. PID control is implemented in present work to control displacement of unsprung mass. The tuning of control parameters is done using Ziegler-Nichols method. Here, Kp= 0.8, Ki= 0.375, Kd= 0.114.

$$fa = Kp + Ki\int_0^t e(t)dt + Kd\,\frac{de(t)}{dt}$$

Where, fa = Actuator force.

4.2. Simulation Results

After simulating suspension system, the main concern from the responses is the body or chassis acceleration. Responses for body acceleration of active and passive suspension for four different combinations as given in table 1 are shown in figures 3, 4, 5 and 6. It is observedfrom figure 3, 4, 5, and 6 that, with the implementation of PID controller, body acceleration of active suspension reduces to almost half of passive suspension. Also, with the increase in damping coefficient, the body acceleration decreases for both active and passive suspension. It is also observed that, with the increase in spring stiffness, body acceleration increases, which is not good for rider's comfort and life of vehicle.

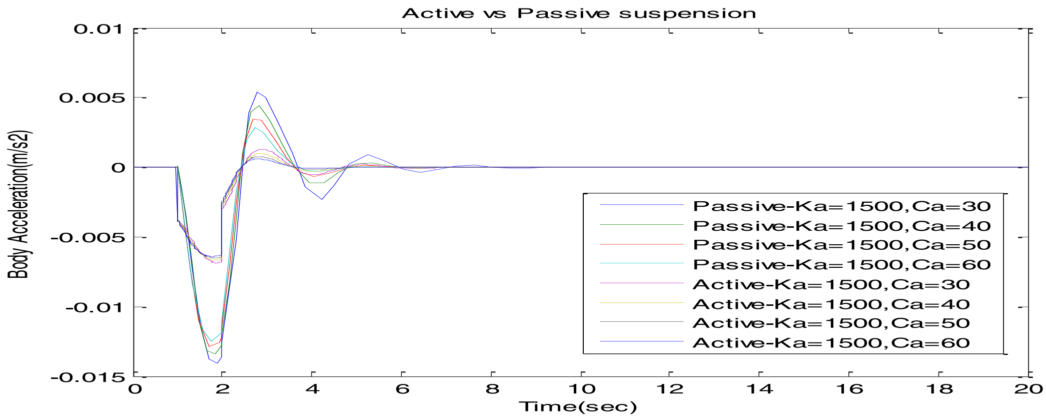

Fig. 3. Body acceleration of active and passive suspension for combination of Ka=1500 and Ca=30, 40, 50, 60.

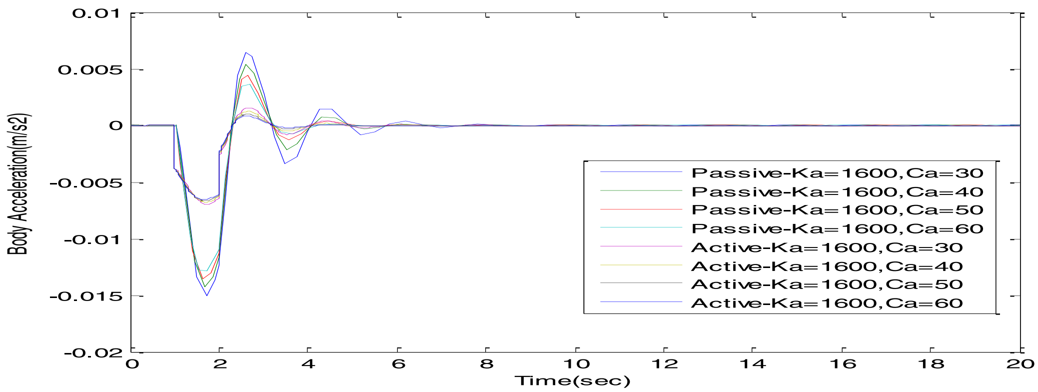

Fig. 4. Body acceleration of active and passive suspension for combination of Ka=1600 and Ca=30, 40, 50, 60.

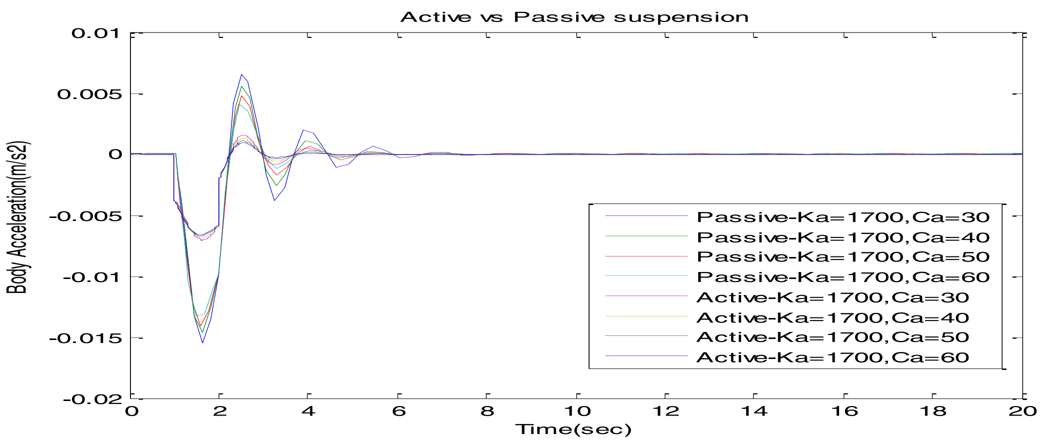

Fig. 5. Body acceleration of active and passive suspension for combination of Ka=1700 and Ca=30, 40, 50, 60.

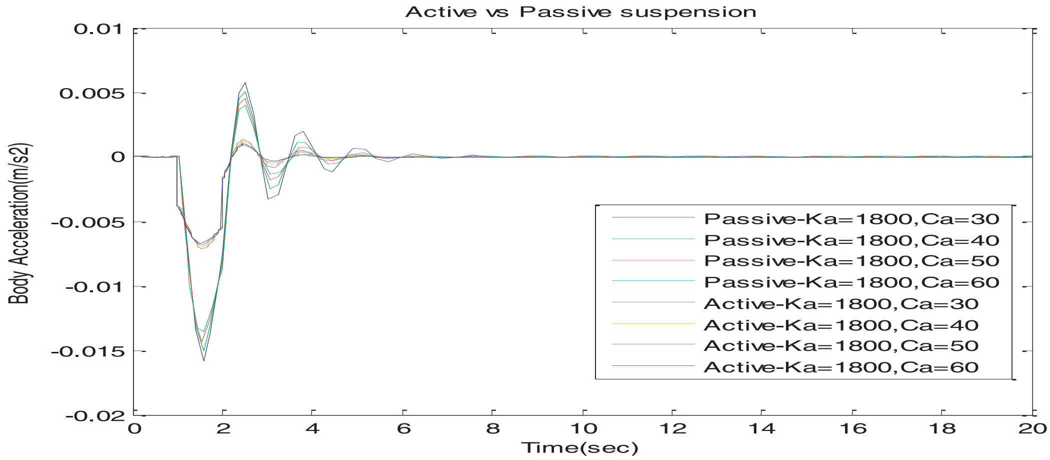

Fig.6. Body acceleration of active and passive suspension for combination of Ka=1800 and Ca=30, 40, 50, 60.

5. Modeling of quarter car wishbone suspension using Simulink

Simulink is a block diagram environment for multi-domain simulation and model-based design available in MATLAB software. It supports system-level design, simulation, automatic code generation, and continuous test and verification of embedded systems. Simulink provides a graphical editor, customizable block libraries, and solvers for modeling and simulating dynamic systems [8]. Simulink model of active quarter car suspension is prepared using mathematical model presented through equations (1) and (2). PID controller is implemented to control the vertical acceleration and improve ride comfort and handling of vehicle.

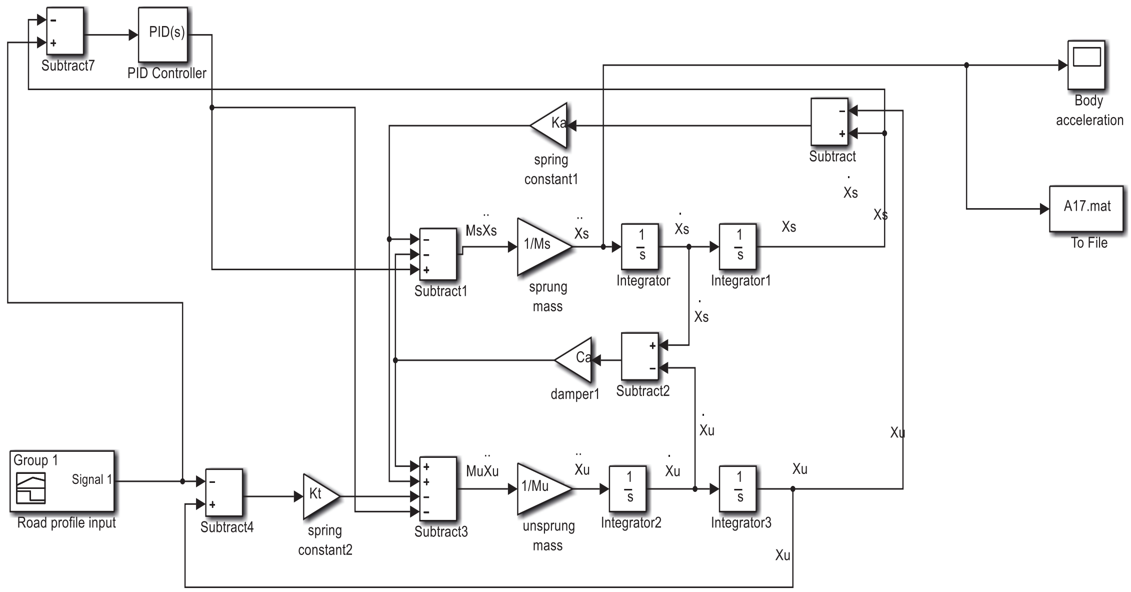

Fig. 7. Simulink model of active quarter car suspension.

Fig. 7 shows the quarter car model prepared in simulink. This model is analyzed for the different combinations of spring stiffness and damping coefficient as shown in table 2.

5.1. Simulation Results

The results for body acceleration of active and passive suspension are obtained from the simulink model of suspension. The results for four different combinations of spring stiffness and damping coefficient as shown in table 2 are shown in figure 8, 9, 10, 11.It is observed from figures 8, 9, 10 and 11 shows that with the implementation of PID controller, there is a drastic change in body acceleration of active suspension compared to passive suspension. It also observed that, with increase in damping coefficient, the body acceleration decreases for both passive and active suspension. Also, with increase in spring stiffness from figure 8 to figure 11, body acceleration increases.

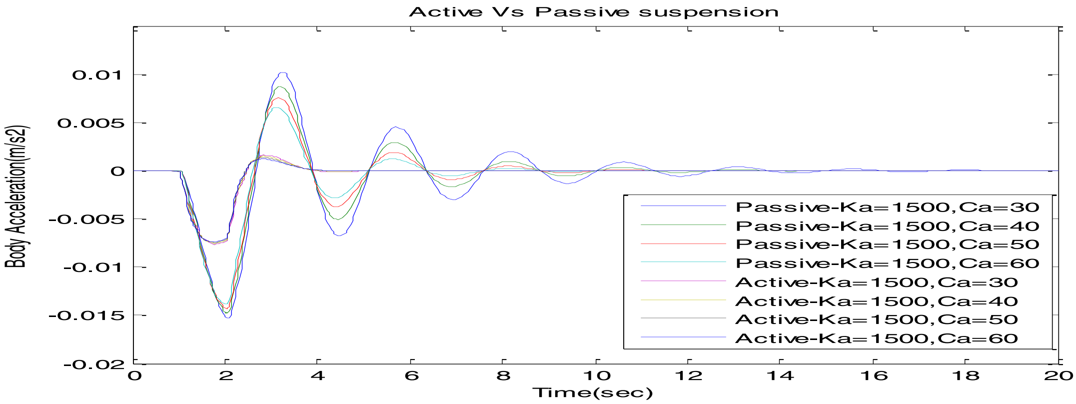

Fig. 8.Body acceleration of active and passive suspension for combination of Ka=1500 and Ca=30, 40, 50, 60.

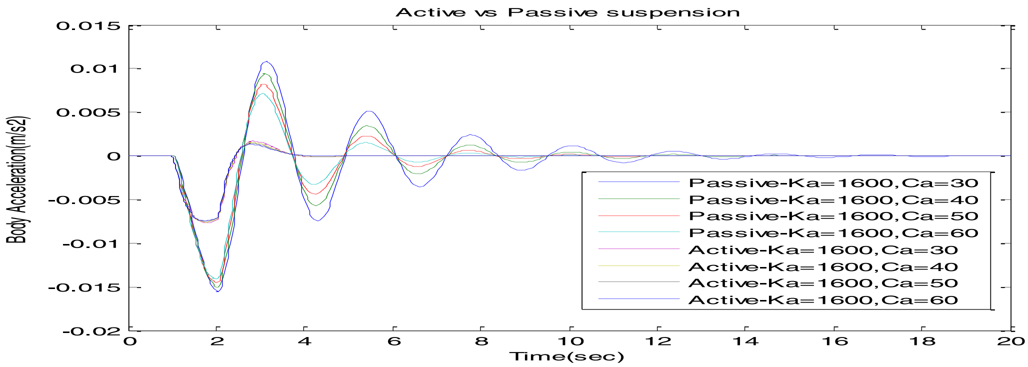

Fig. 9. Body acceleration of active and passive suspension for combination of Ka=1600 and Ca=30, 40, 50, 60.

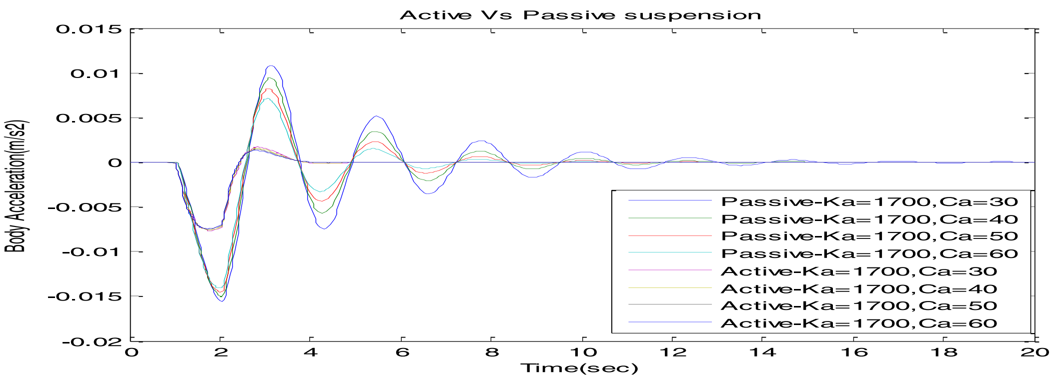

Fig.10. Body acceleration of active and passive suspension for combination of Ka=1700 and Ca=30, 40, 50, 60.

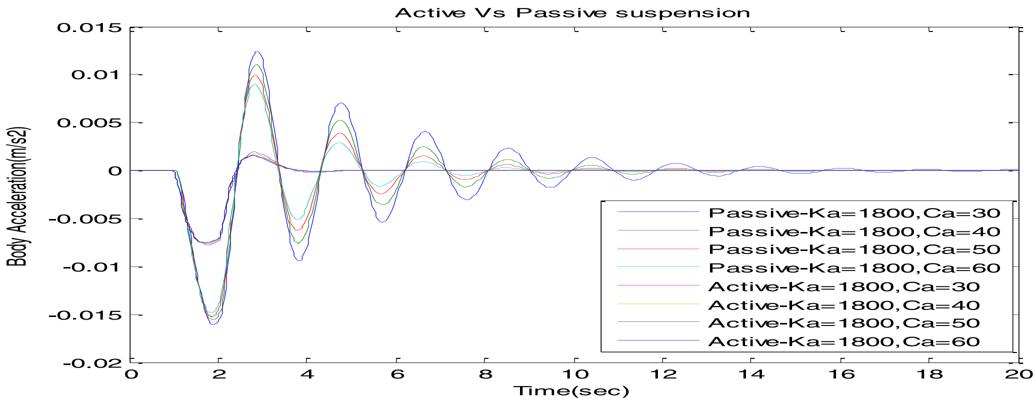

Fig. 11. Body acceleration of active and passive suspension for combination of Ka=1800 and Ca=30, 40, 50, 60.

6. Conclusion

The results of simulation performed using SimMechanics and Simulink shows that, the implementation of PID controller decreases the body acceleration of active suspension to almost half of passive suspension.The ride comfort of passenger can be thus improved by implementing PID controller. The results also show that, body acceleration increases with the increase in spring stiffness and decreases with the increase in damping coefficient.Comparison of both the results shows that, amplitudes of body acceleration of active and passive suspension are similar but, body acceleration of passive suspension takes more time to dissipate in Simulink than in SimMechanics.

References

[1] D. Fischer, R. Isermann, Mechatronics semi-active and active vehicle suspensions, Control Engineering Practice.12 (2004) 1353-1367.
[2] I. Eski, S. Yildirim, Vibration control of vehicle active suspension system using a new robust neural network control system, Simulation Modeling Practice and Theory. 17 (2007) 778-793.
[3] G. Priyandoko, M.Mailah, H.Jamaluddin, Vehicle active suspension system using skyhook adaptive neuro active force control, Mechanical Systems and Signal Processing. 23(2009)855-868.
[4] E. A. Sanchez, A quarter-car suspension system: car body mass estimator and sliding mode control, Procedia Technology. 7 (2013) 208-214.
[5] M. S. Kumar, Development of active suspension system for automobiles using PID controller, Proceedings of the World Congress onEngineering. 2(2008).
[6] P.E. Uys, P.S. Els, M. Thoresson, Suspension settings for optimal ride comfort of off-road vehicles travelling on roads with different roughness and speeds,Journal of Terramechanics. 44(2007) 163–175.
[7] D. A. Mantaras, P. Luque, C. Vera, Development and validation of a three-dimensional kinematic model for the McPherson steering and suspension mechanisms, Mechanism and Machine Theory. 39(2004) 603–619.