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Comparison Of Multibody Dynamic Analysis Of Double Wishbone Suspension Using Simmechanics And FEA Approach

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ABSTRACT*:* *This paper presents the multibody dynamic analysis of wishbone suspension for automotive cars. Modeling and analysis of suspension is carried out using MATLAB SimMechanics toolbox. Rigid dynamic analysis of suspension is also carried out using ANSYS software. Results of both the analysis are compared and it is observed that results of both the analysis are similar.*
Keywords - *Multibody dynamic analysis, Rigid dynamic analysis, Double wishbone suspension, Quarter car suspension*

I. INTRODUCTION

The suspension system consists of spring, damper and the linkages, that connect the vehicle to its wheel. In other words, suspension system is a mechanism that physically separates the car body from the wheel [1]. 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 [2-4].

Multi-body dynamic analysis is the dynamic analysis of mutually interconnected rigid bodies, whose relative motions are constrained by means of joints. The purpose of this analysis is to find out how these bodies move as system and what forces are generated in the process. The multi-body dynamic analysis is typically applied in automobile industry for the modeling and analysis of suspension system. The multi-body suspension models allow precise evaluation of the effect of suspension geometry and the mechanical characteristics of spring and damper on the ride comfort and vehicle handling performance [5].

Taichi Shiiba at el. [5] discussed the performance of a real-time multibody dynamics simulation using linearized constraint equations. Hazem Ali Attia [6] presented the dynamic analysis of the double wishbone motor-vehicle suspension system using the point-joint coordinate's formulation.

Parvir E. Nikravesh [7] presented the joint coordinate formulation for automatic generation of the equations of motion for dynamic analysis of multibody systems. Yuping He at el. [8] designed linear mechanical vehicle model in a multibody dynamics software package A'GEM and implemented the multidisciplinary optimization method in a GA-A'GEM-MATLAB simulation environment. Xiaobin Ning at el. [9] performed dynamic analysis of car suspension using ADAMS/Car for development of a software interface for optimization.

II. MULTIBODY DYNAMICS ANALYSIS USING SIMMECHANICS

SimMechanics is the toolbox of MATLAB, which can be used for simulating the dynamics of multibody system. It computes the dynamics on the basis of block diagram. SimMechanics is based on Simulink, which is a block diagram environment for multi-domain simulation and model-based design in MATLAB software [10]. SimMechanics provides intuitive and effective means of modeling and analysis for multi-body dynamic mechanical system and its control system, and all work would be completed in the Simulink environment. It provides a large number of the corresponding real system components, such as: bodies, joints, constraints, transform, forces and torques, utilities. These modules can be easily utilized to create complex mechanical system model and to analyse a mechanical system. SimMechanics is a member of the Simulink physical modeling, which extends the capability of Simulink modeling. The model created by the SimMechanics can be integrated to the traditional model greatly. It provides a set of modules which can be directly utilized under the Simulink environment. By drawing the various mechanism modules in the common Simulink window and connecting these modules using joints and transform modules, simulation results of the whole system can be obtained. There are six modules of SimMechanics 2^{nd} generation as shown in fig 1.

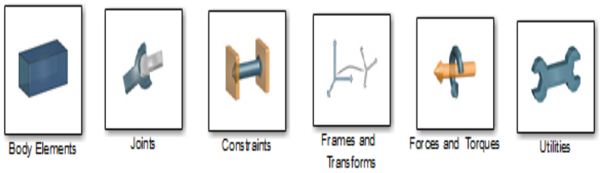

Fig 1: SimMechanics modules

2.1. Modeling and analysis of wishbone suspension using SimMechanics

The quarter car double wishbone suspension is modeled in SimMechanics 2nd generation in MATLAB software. Wishbone suspension is modeled and assembled using SimMechanics 2nd generation toolbox in MATLAB software. The modules shown in fig 1 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 using forces 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 to connect the input block, which is the signal 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.

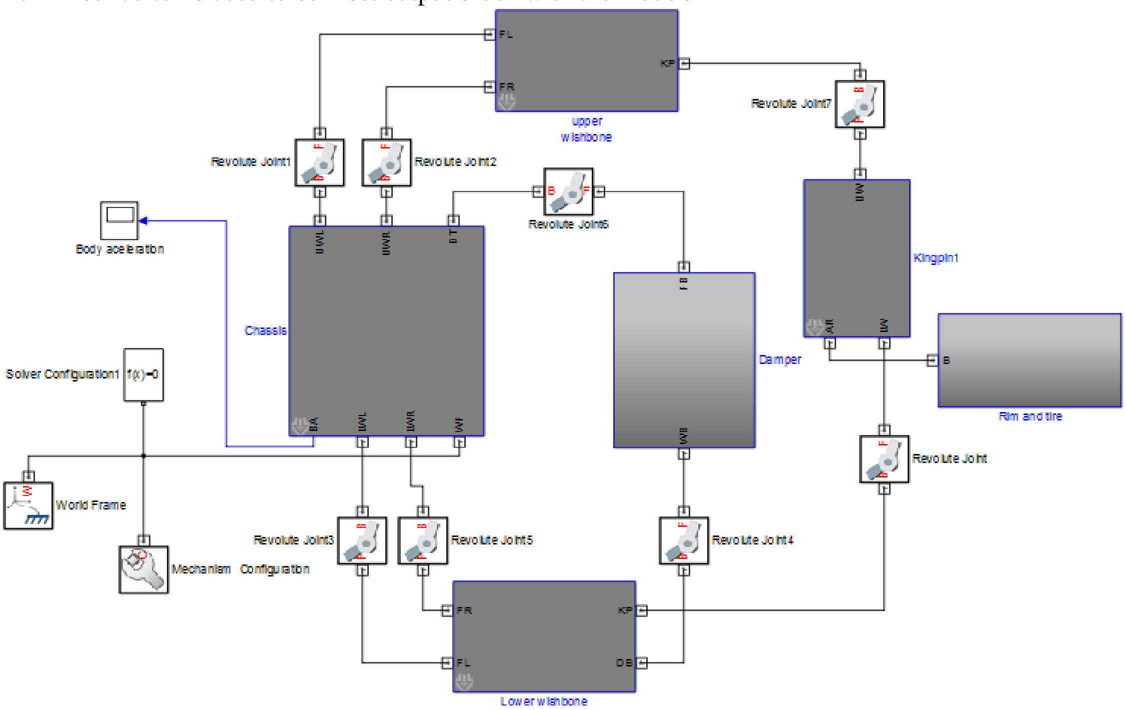

Fig 2: SimMechanics model of quarter car wishbone suspension

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 is given to the wheel and the acceleration of chassis is measured. The spring stiffness and damping coefficient of spring and damper is varied to find out their effect on the acceleration of chassis. The 3D model generated from the block diagram is shown by fig 3.

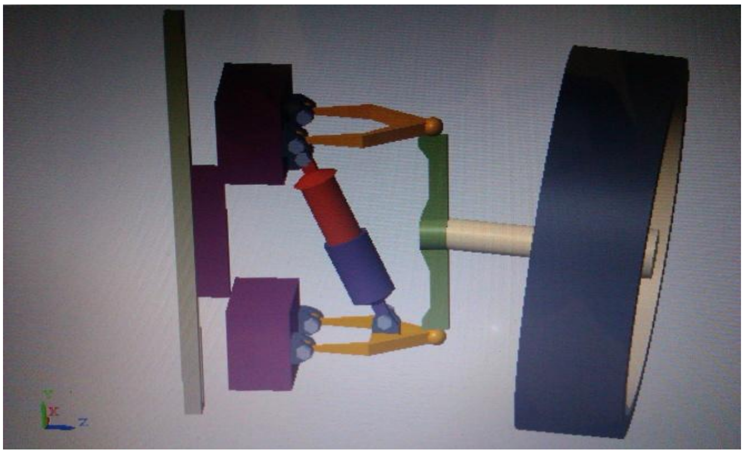

Fig 3: 3D model of double wishbone suspension.

2.2. Road input

The input is given to the wheel in the form of step equivalent to the height of road bump. The signal builder block is used to generate this input. Fig 4 shows the step input equivalent to road bump height.

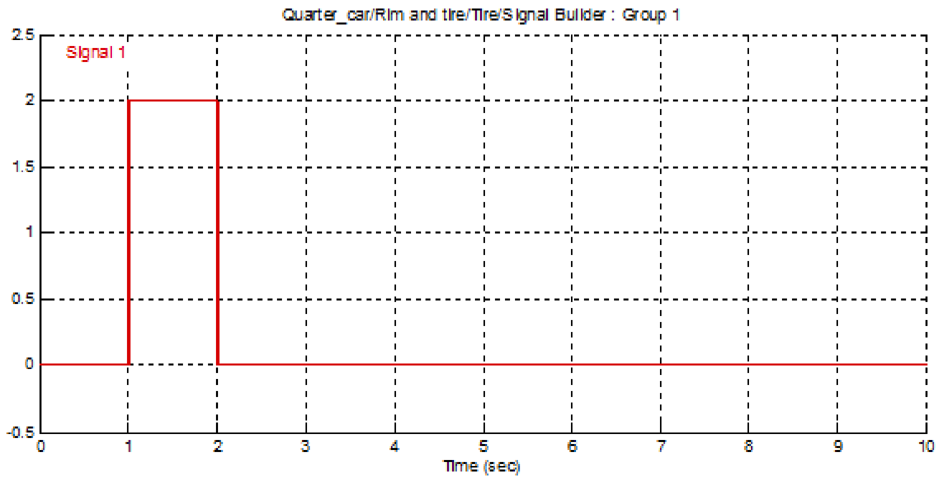

Fig 4: Step input equivalent to road bump height

2.3. Model parameters

Table I shows the different combinations of stiffness and damping coefficient that will be applied to the passive and active suspension model during simulation. The weight of the body is 200 kg, which is added to consider the effect of inertia.

Table I: 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

2.4. Results

After simulating suspension system, the main concern from the responses is the body or chassis acceleration. Responses for body acceleration for four different combinations given in table 1 are shown in figure 5, 6, 7 and 8.

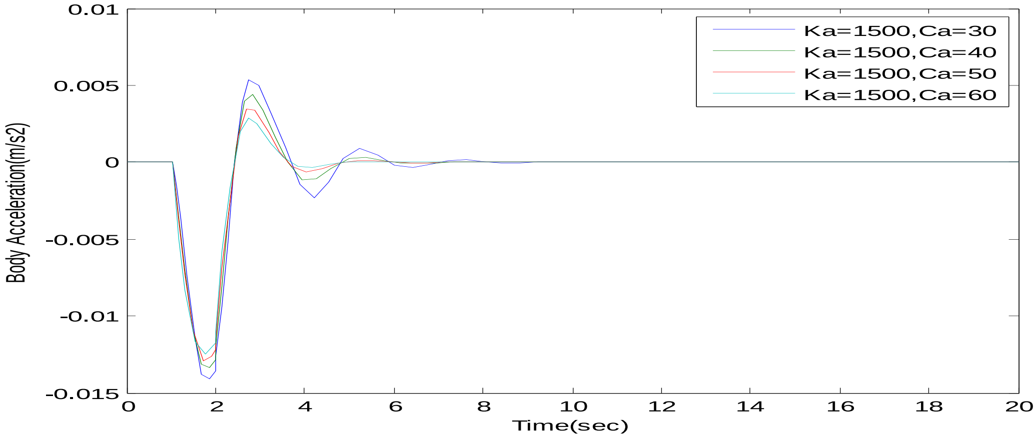

Fig 5: Body acceleration of quarter car suspension for combination of Ka=1500 and Ca=30, 40, 50, 60

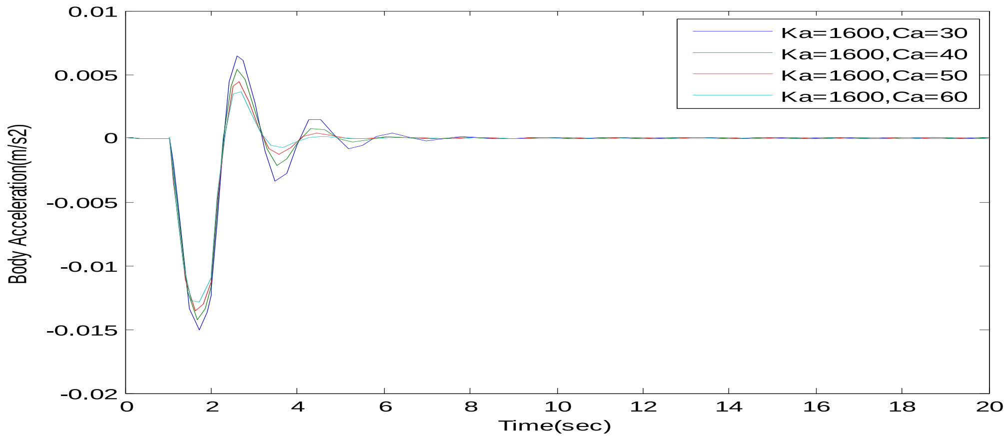

Fig 6: Body acceleration of quarter car suspension for combination of Ka=1600 and Ca=30, 40, 50, 60

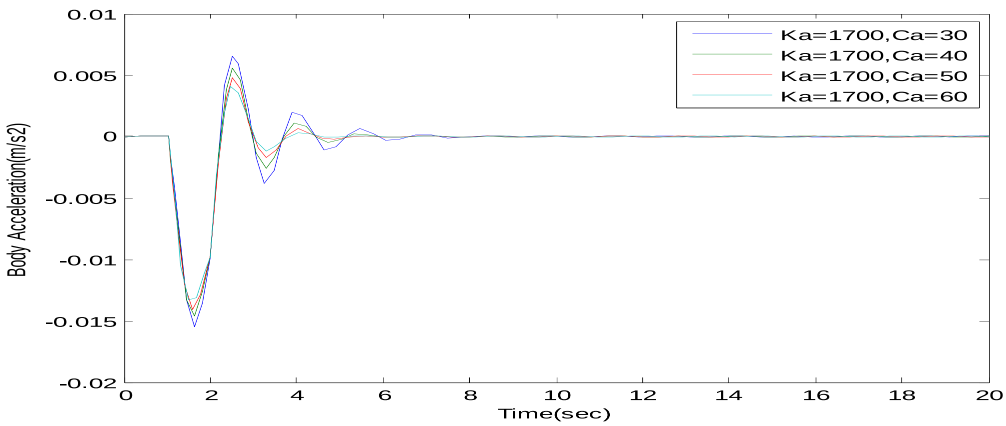

Fig 7: Body acceleration of quarter car suspension for combination of Ka=1700 and Ca=30, 40, 50, 60

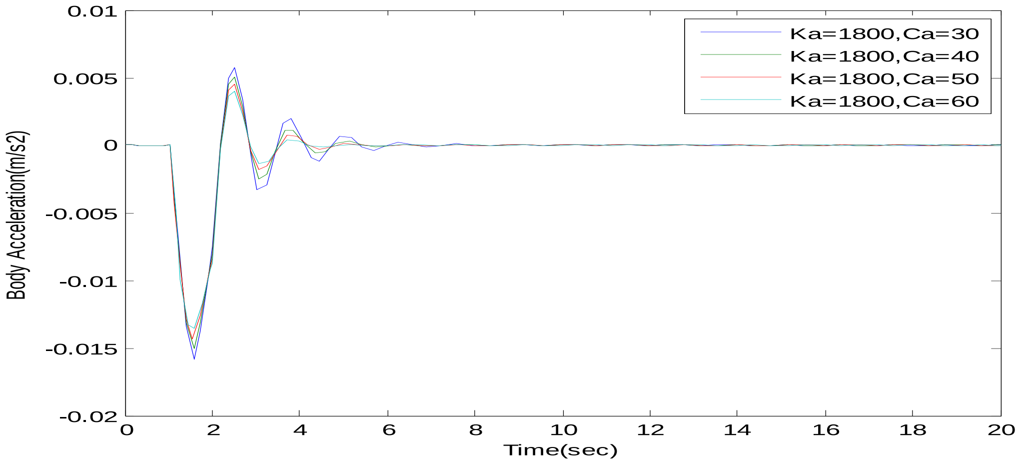

Fig 8: Body acceleration of quarter car suspension for combination of Ka=1800 and Ca=30, 40, 50, 60

III. MULTIBODY DYNAMICS ANALYSIS USING FEA APPROACH

Multibody dynamic analysis can be performed on the wishbone suspension using finite element analysis approach. The analysis can be performed through rigid dynamic analysis in ANSYS software. Rigid dynamic analysis allows the multibody dynamic analysis of rigidly interconnected bodies. This analysis is carried out to obtain the vertical acceleration of the car body. The parameters of suspension like spring stiffness and damping coefficient are varied and their effect on the behaviour of vertical acceleration of the car body is analyzed. The combinations of spring stiffness and damping coefficient shown in table I is used for this purpose.

3.1. Modeling and analysis of wishbone suspension using FEA approach

Multibody dynamic analysis of wishbone suspension using FEA approach requires the CAD model of wishbone suspension. The CAD model of wishbone suspension is prepared using CATIA software. CATIA is the modeling software which provides the tools to prepare a three dimensional model of the system using two dimensional sketches of the components of the system. Each component is modeled separately using part design. The sketch of the component is either extruded or given revolution to form the three dimensional component. Then these components are assembled using assembly design. Each component is imported in the assembly design and then assembled using various constraints to form the three dimensional system.

This model is used for analysis in ANSYS software. The multibody dynamic analysis of wishbone suspension is carried using rigid dynamics analysis which one of the tools of ANSYS software. First, the CAD model is imported in the through geometry. After importing the model geometry, the contacts are established between different components. There are two types of contacts, fixed and movable. The movable contacts are established depending on the degree of freedom of the component. There is revolute contact between kingpin and wishbones. There is also revolute contact between wishbones and bolt of brackets. There is translational contact between damper top and damper bottom. There is also translational contact between frame and frame1, which fixed to the ground. The tyre has the body ground contact and is free to move in all directions and to rotate in about the axis of all the directions. Fig 9 shows the FEA model of quarter car wishbone suspension.

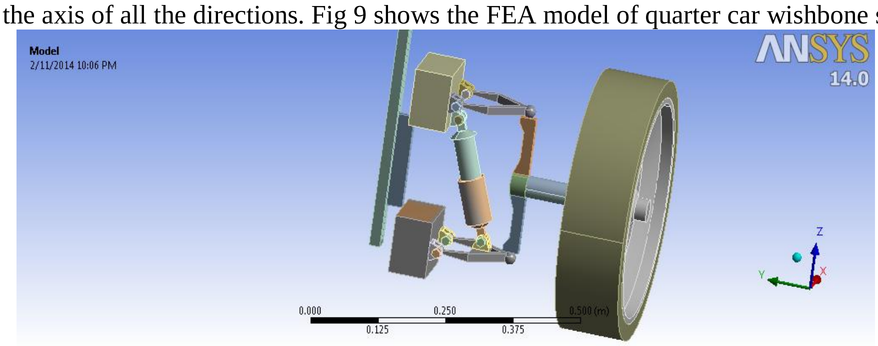

Fig 9: FEA model of quarter car wishbone suspension

3.2. Results

The results for vertical body acceleration are obtained from the rigid dynamics analysis of suspension. Results for different combinations of spring stiffness and damping coefficient are shown in figure 10, 11, 12 and 13.

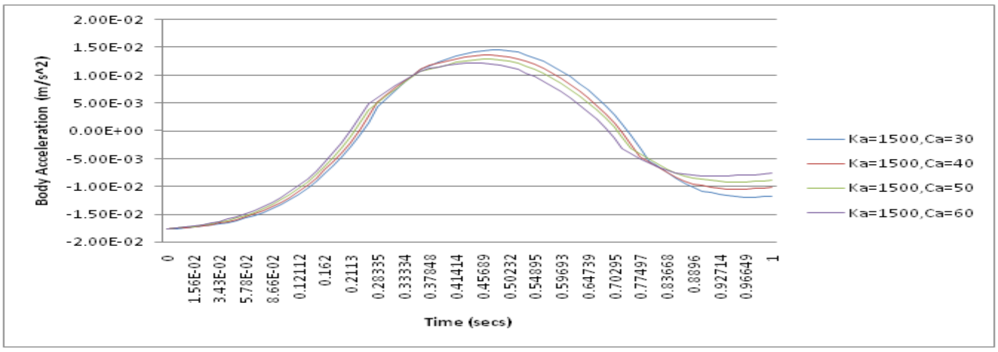

Fig 10: Body acceleration of quarter car suspension for combination of Ka=1500 and Ca=30, 40, 50, 60

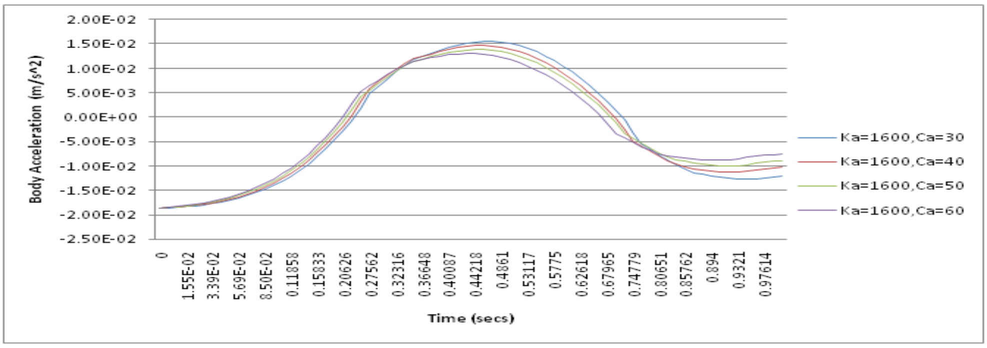

Fig 11: Body acceleration of quarter car suspension for combination of Ka=1600 and Ca=30, 40, 50, 60

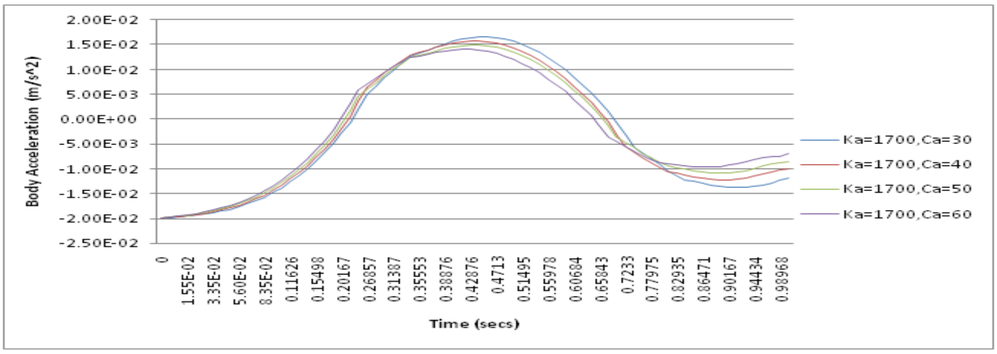

Fig 12: Body acceleration of quarter car suspension for combination of Ka=1700 and Ca=30, 40, 50, 60.

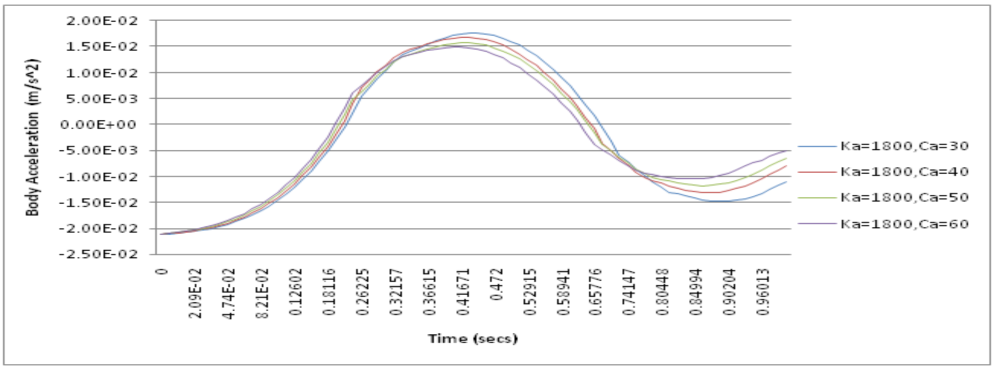

Fig 13: Body acceleration of quarter car suspension for combination of Ka=1800 and Ca=30, 40, 50, 60

IV. CONCLUSION

It can be seen that, for particular combination of spring stiffness and damping coefficient, the results for maximum body acceleration in both the analysis are almost similar. For example, figure 5 and 10 shows similar value for maximum body acceleration for spring stiffness of 1500 N/m and damping coefficient of 30, 40, 50 and 60 N/m/s. This applies to all the combinations of spring stiffness and damping coefficient. Results of both analysis show that, the vertical body acceleration increases with the increase in spring stiffness but decreases with increase in damping coefficient.

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Abhijeet Deshpande is presently working as an assistant professor in VIIT, Pune. He is also pursuing Ph.D. from BVDU, Pune.

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