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Control of Quarter Car Model by Co-Simulation with Adams and Matlab

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Abstract: This work presents an approach to investigate adaptive suspension under different control types by using Adams and Matlab programs simultaneously. A dynamic model of the quarter car model is created in the Adams/View program, and dynamic properties of a car taken from actual four-door car model. By using Adams/Control module the quarter car model created regarding block diagrams. A controller has been added to this system by Matlab. Considering only at vertical displacement, velocity and acceleration can be calculated. These variables show the automobile's performance indicators. These parameters would be improved using co-simulation between Adams and Matlab. This method would be used for faster and proper findings for a controller and ystem design.
Keywords: Quarter Car Model, co-Simulation, control

I. INTRODUCTION

The co-simulation technique is based on the cooperation of different development platforms, which are stronger in their respective areas. By using this technique, different design and analysis programs enable stronger and more realistic simulations. One of the active cooperation is between Adams and Matlab, two widely used engineering development environments [1]. The Adams/Controls module allows connecting the mechanical system models designed in ADAM to block diagrams created in Matlab/Simulink. This connection provides the ability to perform control and analysis operations on a virtual prototype.

In recent years, control and analysis studies have been carried out on a variety of systems using the advantages of co-simulation. Xiu-qin et al. [2] researched the braking performance on ABS of a multi-axle truck by using Adams to model the dynamics of the vehicle and Matlab to design the proposed controller. Li and He [3] also made a demonstration of co-simulation with Adams/Matlab to investigate the handling performance of a vehicle ESP system. Fang et al. [4] proposed a new type of low circuit breaker with permanent magnet actuator. They modeled the dynamics of the prototype by using Adams and analyzed the control model built in Matlab. Silva et al. [5] presented a co-simulation approach of an electric vehicle propulsion system to find out the best configuration regarding battery size and propulsion system setup. Li et al. [6] proposed co-simulation platform with Adams and Easy5, instead of Matlab, to design the model of 360MN extrusion machine and control by six hydraulic cylinders.

Proposed simulation technique has also been used in the control and analysis of various robot platforms. Hadas et al. [7] performed a co-simulation process for several mechatronic systems with flexible parts, such as three dof robot arm, delta robot, and cartesian manipulator. Cheraghpour et al. [8] proposed co-simulation method as a precise simulator by using Adams and Matlab as a co-simulation environment for dynamic modeling and control analysis. They examined the tracking performance for a predefined pose of an industrial robot, Stäubli TX40. Pan et al. [9] analyzed a legged exoskeleton robot which is a nonlinear system because of uncertain parameters. They proposed fuzzy-PID control approach and compared the performance with PID controller by performing co-simulation with Adams and Matlab. Also, Cigánek [10] designed a controller based on fuzzy logic approach and analyzed the trajectory tracking performance of the proposed controller by using co-simulation method with Adams and Matlab.

II. SYSTEM MODELING

In this study, a co-simulation process is performed for the quarter vehicle suspension model. The primary purpose of the suspension systems is to reduce the vertical acceleration transmitted to the driver, to provide ride comfort and vehicle stability [11]. The physical model of this mechanical system used in the study is given in Figure 1, and the system parameters are given in Table 1.

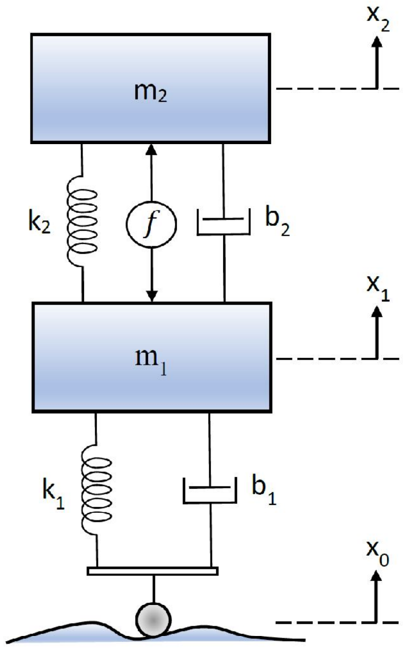

Fig. 1.Physical model of quarter car active suspension system.

TABLE 1.
The parameters of the quarter car active suspension system.

Parameter	Symbol	Value & Unit
Body Mass	m_2	350 kg
Suspension Mass	m_1	47 kg
Spring Constant of Suspension System	k_2	7.000 N/m
Spring Constant of Wheel and Tire	k_1	142.000 N/m
Damping Constant of Suspension System	b_2	180 N.s/m
Damping Constant of Wheel and Tire	b_1	6.000 N.s/m
Control Force	f	N

Based on the physical model in Fig. 1, the system dynamics can be expressed by equation (1) and equation (2). An active suspension is provided considering the “f” force in the equations, and the passive suspension is provided when it is not.

$$m_2\ddot{x}_2 = -b_2(\dot{x}_2 - \dot{x}_1) - k_1(x_2 - x_1) + f \quad (1)$$

$$m_1\ddot{x}_1 = b_2(\dot{x}_2 - \dot{x}_1) + k_2(x_2 - x_1) - b_1(\dot{x}_1 - \dot{x}_0) - k_1(x_1 - x_0) - \quad (2)$$

The system model to be used for co-simulation is prepared in Adams/View program. This designed Adams model is shown in Fig. 2.

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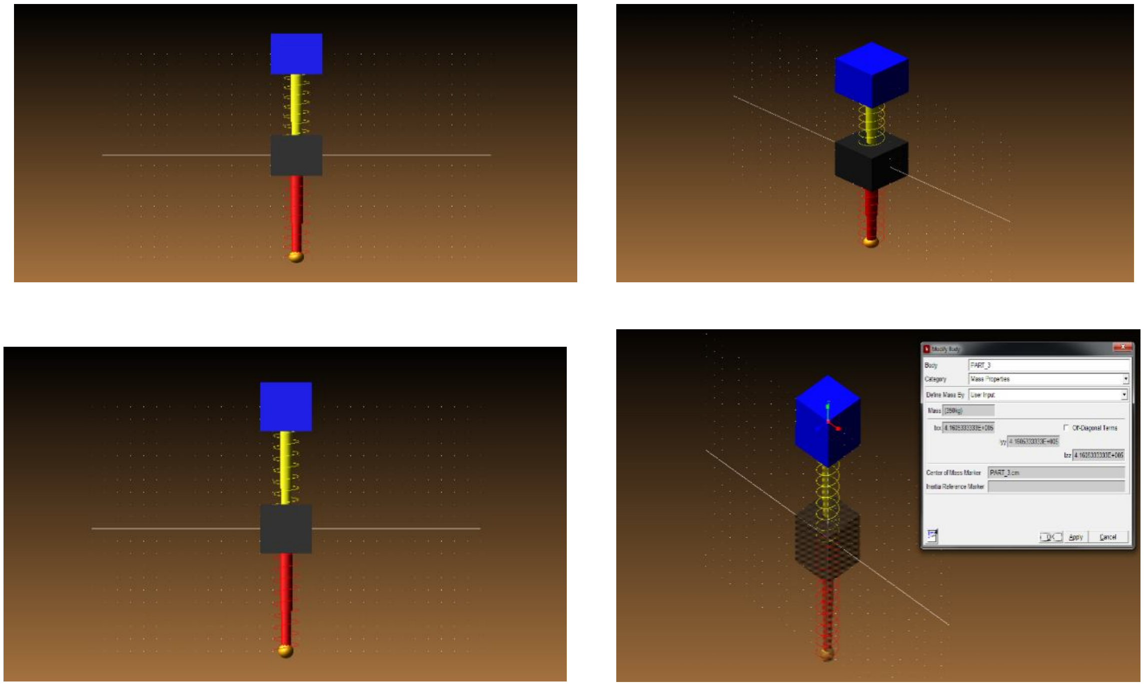
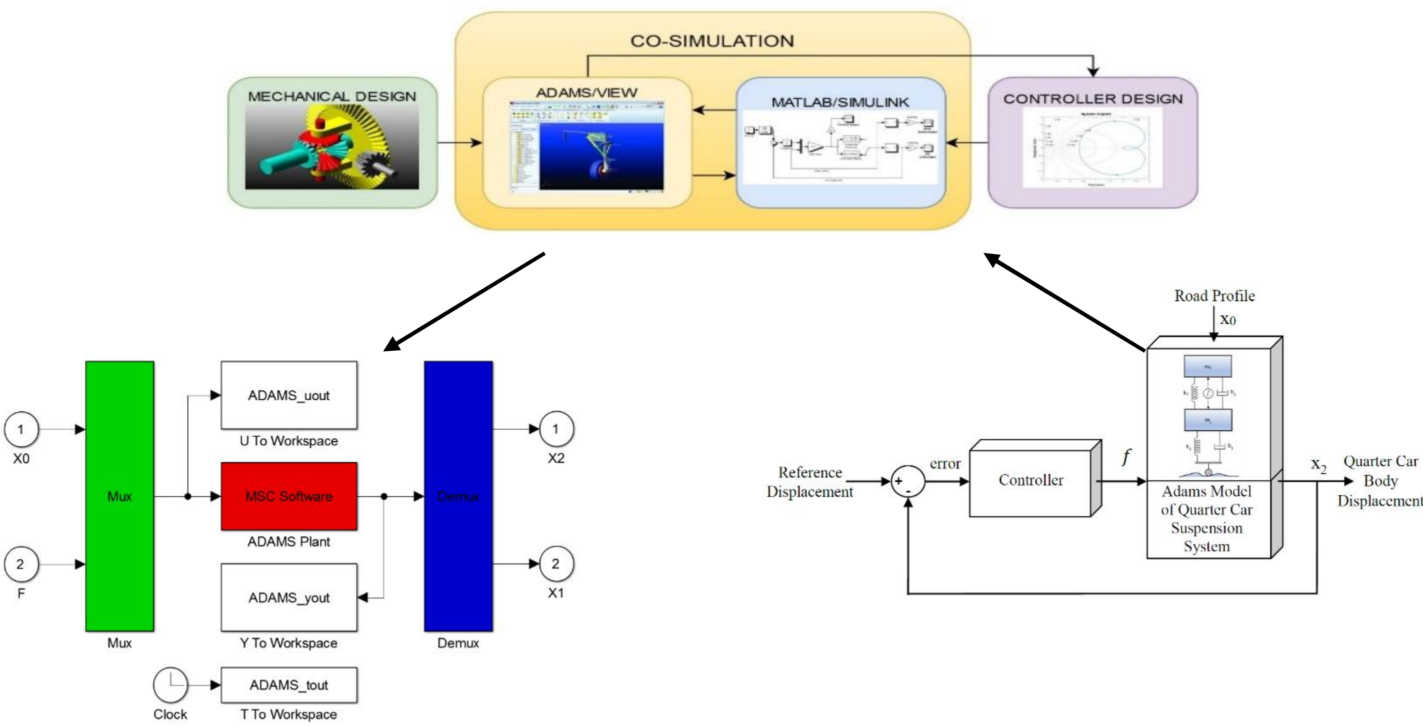


Fig.2. The system model to be used for co-simulation is prepared in Adams/View program.

III. CONTROLLER DESIGN

The co-simulation is valuable when the procedure can speed up the user during the design of the systems and display the simulation results instantaneously. Although the modeling of the system is a one-time operation, once the system is in control, the parameters will indicate the instant response system whether the system meets the desired requirements. At this stage, the previously mentioned system model is also formed in Adams view. The system is running for different road conditions. Different types of control approaches have been implemented and compared to these road conditions. The PID control element was selected as the controller. There are two different ways to determine the control parameters. The first one is the Ziegler Nichols method, and the other is the auto-tune option used in the Matlab program.



IV. SIMULATION RESULTS

The performance of the PID controller, determined by Ziegler Nichols parameter determining the procedure and auto-tune has been performed for three different road profiles. These path profiles were applied as step, sinus and random signals. Simulation results show that the controller with parameters set by Auto-tune performs better damping and the displacement of the vehicle body and it shows that better controlled. The obtained simulation results are shown in graphical form in Fig. 6 for step input, Fig. 7 for sinus input and Fig. 8 for random signal input.

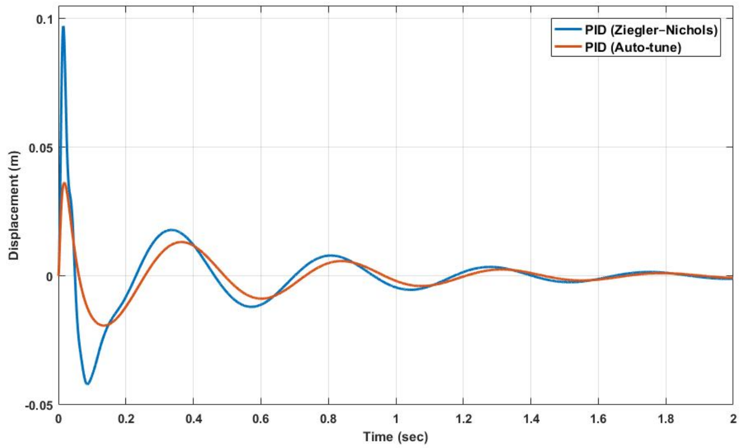


Fig.4. Control of body displacement for road profile in step signal form.

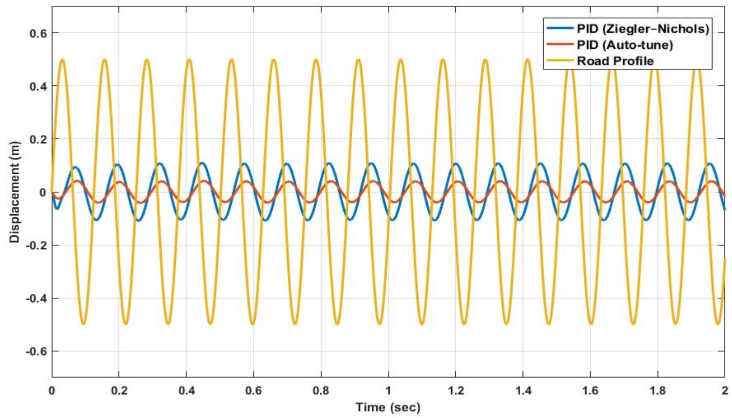


Fig.5. Control of body displacement for road profile in sinus signal form.

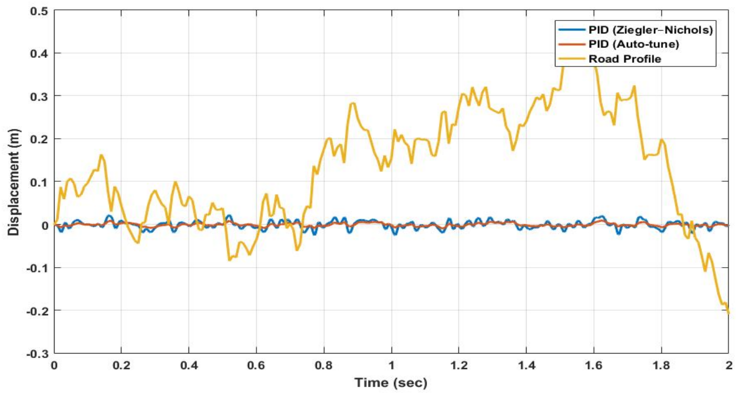


Fig.8. Control of body displacement for road profile in random signal form.

V. CONCLUSION

In this paper, a co-simulation method is applied to investigate adaptive suspension system behaviors for a quarter car model. MSC Adams program is used to create the dynamic model of the system to build a virtual prototype, and the model is cross-connected to Matlab-Simulink environment to apply the control algorithm. PID controller is used to controlling the vertical displacement of the quarter car model with gain parameters calculated by auto tune method of Simulink PID toolbox. The results showed the performance of the co-simulation method to overcome the difficulty of dynamic system modeling and reduce the controller development time. Also, future work could focus on different control algorithms to examine the effectiveness of the presented co-simulation method.

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