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Modeling and Controller Comparison for Quarter Car Suspension System by Using PID and Type-1 Fuzzy Logic

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Abstract. Ensuring vehicle drive comfort and securing drive safety are the leading topics among the most interested issues for researchers in vehicle dynamics area. In this paper, a method utilizing a linear actuator is proposed for active control of the vehicle vibrations which are caused by road profile, intending to improve drive comfort and safety of road vehicles. The mathematical model belonging to the system that is evaluated as two degrees of freedom quarter car suspension system is derived by using Lagrange Equation of Motion and MATLAB/Simulink software. In addition to modeling technique, dynamic model of proposed system is created in MSC-ADAMS software and it is simulated in both Matlab and Adams programs together. Moreover two different controllers are designed, which are PID and Artificial Neural Network Based Fuzzy Logic (ANNFL) control in order to use in active vibration control simulations. Performances of the designed controllers are examined and the suitability of the designed controllers is studied by comparing their performances in case of using two different road profile functions.

Introduction

Main problems to be overcome on vehicles are driving safety and ride comfort. Vehicles are exposed to vibrations with different frequencies occurring by road profile, driving style and vehicle dynamics. The only way of the increasing ride comfort and driving safety on road vehicles is suspend the vibrations. In vehicles, suspension systems are used to reduce vibrations. Researches have shown that many different control methods have been developed to ensure the ride comfort and driving safety [1-9]. Due to this need, semi-active and active suspension systems have developed. Generally, the vehicle suspension models are divided into three types namely quarter car [1], half car [2] and full car [3] models.

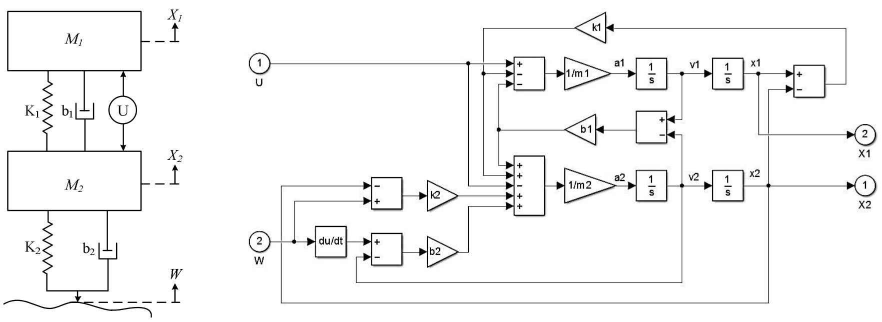

Figure 1. Shematic diagram and Matlab/Simulink model of quarter car suspension system.

The main objective of this study is to use two different modeling programs together as MATLAB and ADAMS for passive mode responses of proposed quarter car model and the performance analyses of designed PID and ANNFL controllers for active vibration control of quarter car suspension system. All results are presented for passive and active mode responses of proposed system in the form of graphics.

Mathematical Modelling

In passive suspension systems, vibration reducing function is provided by conventional dampers. In active suspension systems, an actuator is added between sprung and unsprung mass (between vehicle body and wheel group) to adjusting the damping force to reduce vibrations. Schematic diagram of active suspension system is given Figure 1. Langrange formulation $L = T - V$ is used to obtain equations of motion of quarter car suspension system in Equation 1 and 2 respectively [6]. Also Lagrange formulation based Matlab/Simulink block diagram of suspension system is shown in Figure 1.

$$M_1\ddot{X}_1 = -b_1(\dot{X}_1 - \dot{X}_2) - K_1(X_1 - X_2) + U \quad (1)$$

$$M_2\ddot{X}_2 = b_1(\dot{X}_1 - \dot{X}_2) + K_1(X_1 - X_2) + b_2(\dot{W} - \dot{X}_2) + K_2(W - X_2) - U \quad (2)$$

Table 1. Parameters of the quarter car model.

M_1	Sprung Mass	350 kg
M_2	Unsprung mass	40 kg
K_1	Spring constant of suspension system	18000 N/m
K_2	Spring constant of wheel and tire	195000 N/m
b_1	Damping constant of suspension system	600 Ns/m
b_2	Damping constant of wheel and tire	800 Ns/m
U	Control force	N

Used parameters of the quarter car model are given in Table 1. According to these parameters two degrees of freedom quarter car suspension model is constituted in ADAMS environment to analyze dynamic behavior of suspension system [6]. The three-dimensional solid objects represent masses of vehicle and wheel, are created and attached to each other by spring and damper elements.

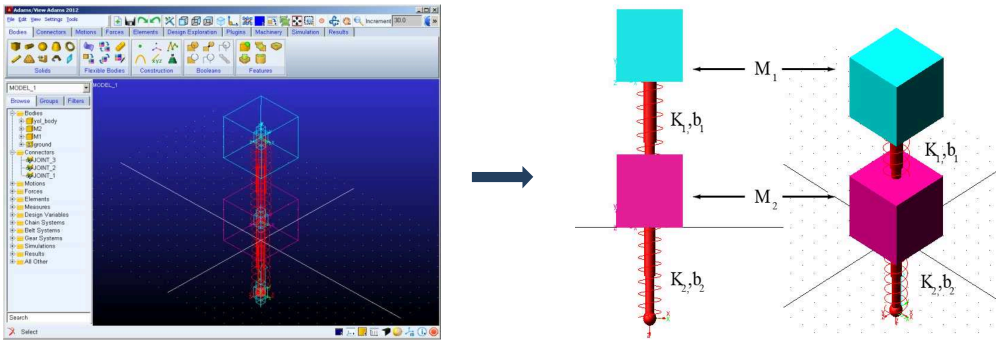

Figure 2. ADAMS model of suspension system.

ADAMS model of suspension system shown in Figure 2 is imported to MATLAB/Simulink to verify both modeling methods. Also passive mode response comparison of both softwares is given in Figure 3 against to step input as road smoothliness.

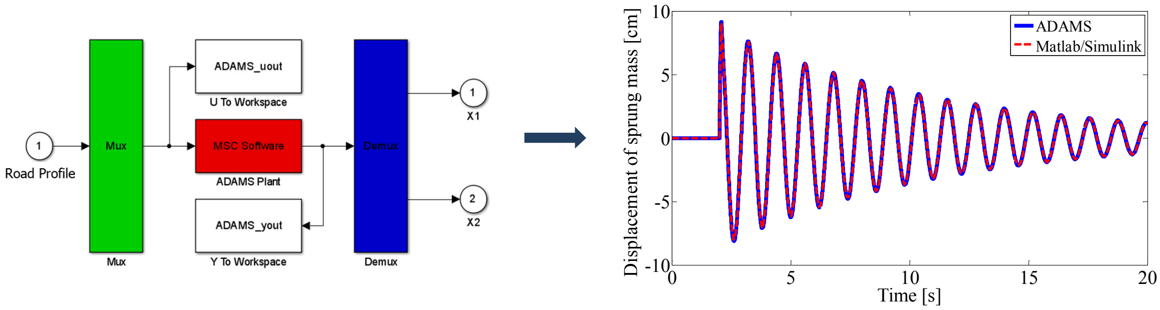

Figure 3. Adams and Matlab/Simulink co-simulation and passive mode response comparison.

Controller Design

PID and ANNFLC controllers are used to reduce quarter car vehicle body displacement. PID gain parameters Kp, Ki ve Kd are tuned by using Matlab/PID Toolbox and these parameters obtained as Kp=9420539.97966783, Ki=31494229.8613296 ve Kd=111358.708912789. Training and testing data of ANNFLC are determined by using behaviour of PID controlled quarter car active suspension system. Membership functions are given in Figure 4.

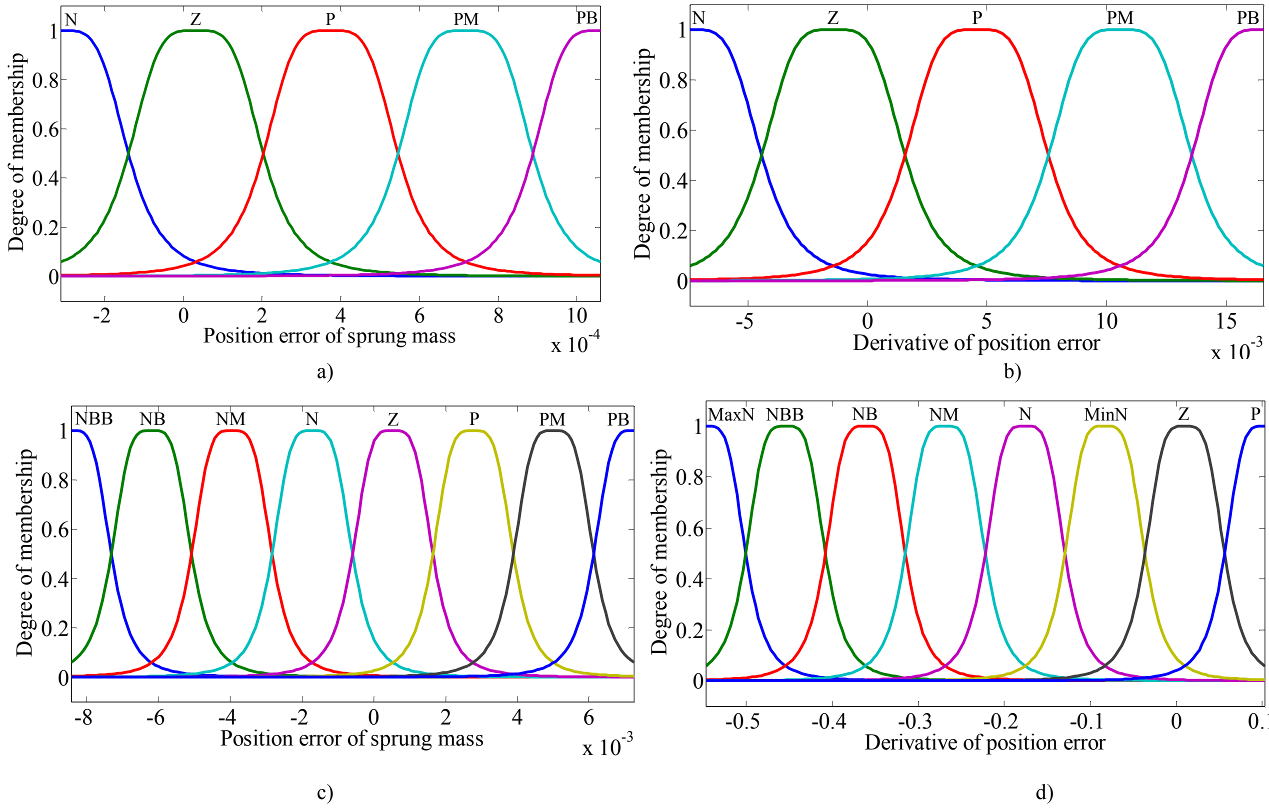

Figure 4. a-b) Membership functions for sinus input. c-d) Membership functions for step input.

Two different road profile functions are used in order to examine the performance of the system. These are three different frequencies such as sinusoidal and step functions. Neural network structure and control methodology for quarter car suspension system is given in Figure 5.

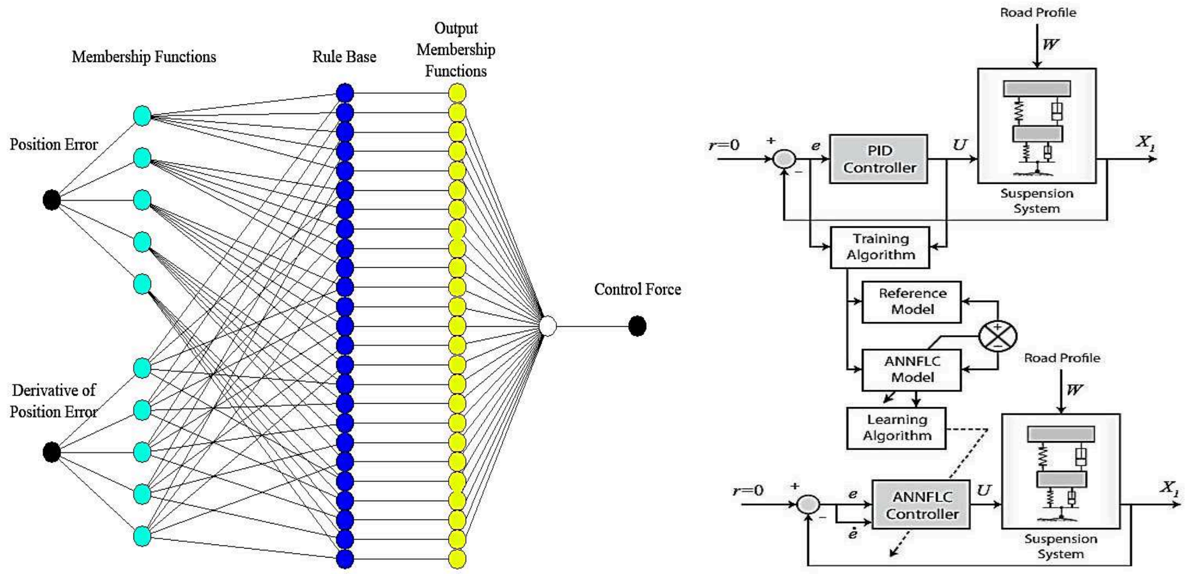

Figure 5. Neural network structure and control methodology of quarter car suspension system.

The effectiveness of the proposed controllers is tested by simulations. The objective in this simulation is to tune controllers for displacements of the sprung mass of the quarter car system. Uncontrolled (passive mode), PID and ANNFLC controlled displacements of the sprung mass are compared and presented in Figure 6. As seen from the figures, both controllers significantly reduce vibration of the sprung mass of the quarter car system. From these results it can be said that ANNFLC controller more effective than PID controller for active vibration control of suspension system in simulations.

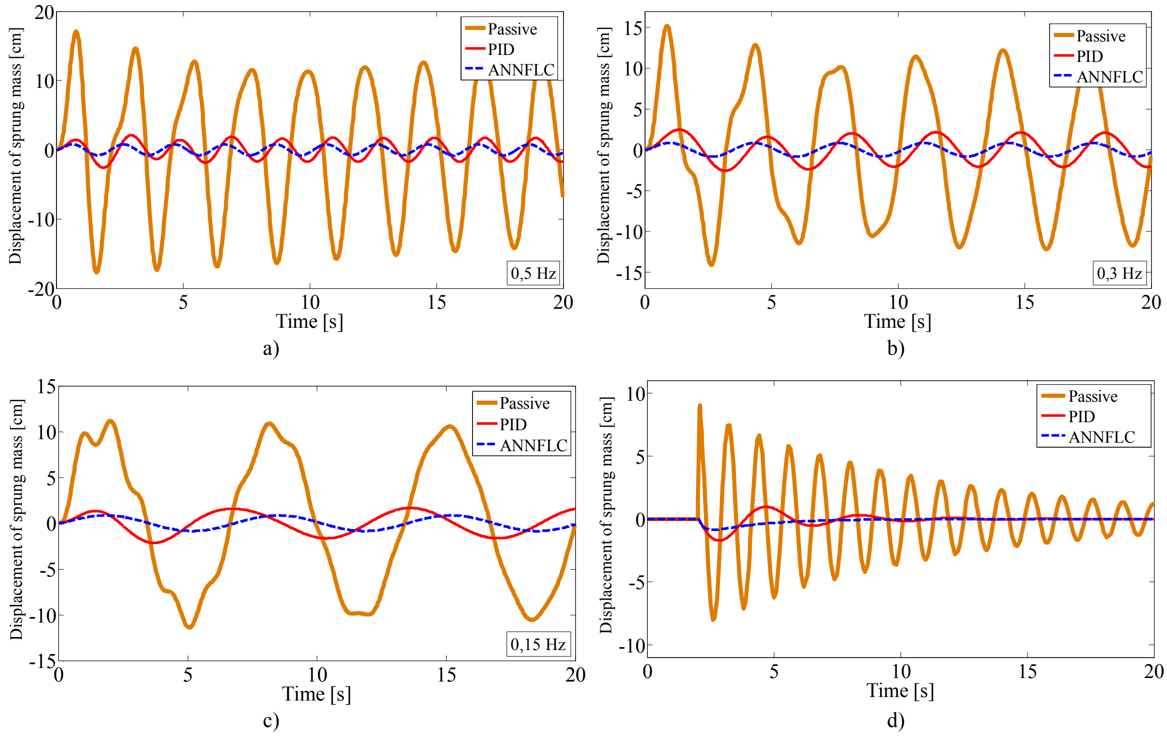

Figure 6. a-b-c) Sinusodial road profile results , d) Step road profile results.

Conclusion

This paper presents modeling and active vibration control of quarter car suspension system by using MATLAB and ADAMS programs and different types of controllers design against to two road profiles. According to modeling and control results, used techniques and implementations are achieved well and important informations are obtained for next experimental works successfully. Moreover differences between passive and active modes are determined and the effectiveness of developed controllers is verified by using simulations.

Acknowledge

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