

# Chapter 44

## Online Adaptive Neuro– Fuzzy Based Full Car Suspension Control Strategy

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### ABSTRACT

*Suspension system of a vehicle is used to minimize the effect of different road disturbances for ride comfort and improvement of vehicle control. A passive suspension system responds only to the deflection of the strut. The main objective of this work is to design an efficient active suspension control for a full car model with 8-Degrees Of Freedom (DOF) using adaptive soft-computing technique. So, in this study, an Adaptive Neuro-Fuzzy based Sliding Mode Control (ANFSMC) strategy is used for full car active suspension control to improve the ride comfort and vehicle stability. The detailed mathematical model of ANFSMC has been developed and successfully applied to a full car model. The robustness of the presented ANFSMC has been proved on the basis of different performance indices. The analysis of MATLAB/SIMULINK based simulation results reveals that the proposed ANFSMC has better ride comfort and vehicle handling as compared to Adaptive PID (APID), Adaptive Mamdani Fuzzy Logic (AMFL), passive, and semi-active suspension systems. The performance of the active suspension has been optimized in terms of displacement of seat, heave, pitch, and roll.*

### INTRODUCTION

Suspension system is a common property of all vehicles. Suspension system isolates the vehicle body from the road disturbances to improve ride comfort and good road handling. Ride comfort and good road-handling performance of a vehicle

are generally analyzed by the damping feature of the shock absorbers. A vehicle suspension may be classified as passive suspension, semi-active suspension and an active suspension system. Passive suspension system comprises springs and shock absorbers (Giua et al, 1999). The springs are supposed to have a linear feature and shock

DOI: 10.4018/978-1-4666-7456-1.ch044

absorbers exhibit nonlinear affiliation between force and velocity. So, in passive suspension systems, these components have fixed characteristics and have no means for feedback control. Whereas, the semi-active suspension system changes the damping coefficient by the electromagnetic regulator inside the absorber. The important feature of the active suspension system is that a peripheral power source is applied to attain the desired suspension objective. The actuator in the active suspension system is placed as a secondary suspension system for the vehicle. The controller drives the actuator, which depends on the proposed control law. The active suspension system gives the freedom to tune the whole suspension system, and the control force can be initiated locally or globally depending on the system state. Also, the active suspension system has the supplementary advantages, because, in this suspension system the negative damping can be afforded and a large range of forces can be produced at low velocities. This shows potentially allocating improvement in the system performance. The selection of control strategy is very important in the active suspension system. With proper control strategy, it will present improved coalition between ride comfort and vehicle stability. Initially many researchers assumed that the vehicle models are linear, but these models have some nonlinearities, like dry friction on the dampers. These nonlinearities can affect the vehicle stability and ride comfort.

In the last few years, researchers applied different linear control methods and non-linear control methods to the vehicle suspension models (Lin F. et al, 2000; Yue et al, 1989). Many researchers carried out studies on active suspension system (Hac, 1987) on a quarter car model due to the simplicity of this model. The best performance assessments of variable suspension system on a quarter car model are examined by (Bigarbegian et al, 2008), but only gave information about the heave of the model and seems overlooked the rattle space limit. Many control techniques have also been examined for the quarter car case like

optimal control (Alleyne & Hednck, 1995), nonlinear control (Alleyne et al, 1997) and backstepping control (Lin et al, 2003) however, they could not identify the uncertainty in the plant parameters. The passenger suspension seat was taken into account in their control technique by (Nicolas et al, 1997). The quarter car model described the passenger suspension seat with nonlinearities like shock absorber damping, bump stops and linkage friction. Since this model does not give the sufficient information about the vehicle's angular motion, therefore, vibration control and dynamic behavior of a half car suspension model is investigated by various researchers in (Hac A., 1986). Some optimal control approaches have also been investigated for the full vehicle suspension system (Chalasan, 1996; Elbeheiry et al, 1996). Many researchers (Crolla & Abdel Hady, 1991; Cech, 1994) have investigated to control the heave, roll and also the chassis of vehicle, but did not give any information about the robustness to system parameter variations. Ahmadian and Pare (2000) used optimal control laws to compare the performances of the passive suspension system and active system suspension on quarter car model, half car model and full car model. Mouleeswaran (2008) applied PID controller on an active suspension system. Study on nonlinear active suspension system (Alleyne & Hedrick, J. K., 2009; Hana, D., 2010) was carried out. Some comparison of PID controlled active suspension and sliding mode controlled active suspension is proposed (Guclu & Yagiz, N., 2004). Also PI sliding mode control (Alleyne et al., 1997) is applied on an active car suspension system. (Rahmi, G., 2003) examined the active control of seat vibrations of a vehicle model using various suspension alternatives.

PID control technique is pertained as a conventional law. Since this control technique can be applied broadly and widely, it has performed significant role in control applications. But, this control method is sensitive to parameter changes. If the plant changes their parameters due to uncertainties, then PID controller cannot update their

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