

# Chapter 3

## Design and Evaluation of Hydro–Pneumatic Friction Damper Suspension System

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### ABSTRACT

*Perceived comfort level and ride stability are the two most important factors in the evaluation of suspension system in a mobile vehicle. It is extremely difficult to simultaneously maintain a high standard of vehicle ride, handling and body control in the vehicle by using conventional passive suspension system. However, the use of active suspensions would result in better comforts than the passive ones. This paper presents the design and analysis of a pneumatic friction damper and hydro-pneumatic friction damper. A non-linear quarter car model is developed, which includes pneumatic actuation by pressure regulation. The performance of the proposed model was assessed in terms of level of vibration reduction. Simulations on a prototype model show that the proposed system has good performance and robustness.*

### 1. INTRODUCTION

The main functions of a vehicle suspension system are to isolate the body from road unevenness disturbances and to maintain the contact between the road and the wheel. Therefore, the suspension system is responsible for the ride quality and driv-

ing stability. The design of a passive suspension system is a compromise between this conflict demands. However, the improvement in vertical vehicle dynamics is possible by developing active suspension system. In recent years, the development of pneumatics controlled suspension dampers and actuator has increased the research

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on vehicle safety versus ride comfort trade off. In order to maintain the level of comfort for passengers and drivers, and still maintain the high safety standards of automobiles, suspension designers have been forced to look beyond the conventional suspension systems.

Crosby and Karnopp (1974) originally proposed the basic concept of semi-active damping and then the use of semi-active dampers in automobiles has been studied extensively. The authors have contributed an excellent review of many of the past efforts in the area of semi-active suspension design and provided a background of the information that is required to understand semi-active suspension systems. A review of the state-of-the-art of controlled suspensions has been carried out by Hedrick and Wormely (1975) and by Goodall and Kortum (1983). In these investigations, semi-active control and linear optimal control with full state feedback along with simple on-off control strategies were employed to reduce both the tyre force and body acceleration of a heavy truck. However, it is worth mentioning here that the air springs for passenger cars are commercially available and there are not enough researches devoted on their performances. The work presented by Quaglia and Sorly (1996) discussed the vehicular air suspensions from design aspects, but not from control viewpoint. Considering the market requirement for passenger vehicles, it was found that integration of leveling, variable damper control technology and stiffness control are very beneficial. The new active friction damper provides a possible solution for the problem.

There are two basic types of suspension namely, the primary suspension used between the vehicle chassis and axle assembly and secondary suspension system mounted between the vehicle body and seat. Much work has been reported (Reynolds, 1993; Rayleigh, 1945) regarding the primary and secondary suspension systems. The study carried out by Williams (1997) classified

the active suspensions as the high-bandwidth (fast active) and low bandwidth (slow active). High bandwidth active hydraulic actuators control the body motion and wheel motion. On the other hand, low bandwidth suspensions employ pneumatic actuators to control the body motion while the wheel motion is controlled by conventional passive spring and damper. Over the past three decades, many control methods for active suspension have been studied. Review studies by Clarr and Vogel (1989) and Sharp and Corolla (1987) summarized the various commonly used control techniques. More recently, controls based on different approaches have been employed in active suspension system. These include approaches based on linear and non-linear control (Gao et al., 2006; Hong et al., 2002; Elimadany & Abdlizabbar, 1999), optimal control (Elbheiry & Karnopp, 1996) and modern robust control such as H-infinity (Palmeri et al., 1995; Stribrsky et al., 2002; Wang et al., 2001). In the past, Fuzzy logic based active and semi-active suspension system (Kashani & Strelow, 1999) was also being employed for the control purpose. Among them, skyhook control (Hong et al., 2002) is the most important concept considered for active suspensions.

The main aim of this paper is to discuss the investigations carried on the pneumatic friction and hydro-pneumatic friction dampers. In this approach, laboratory prototype models of the aforementioned friction dampers have been developed. In order to study the complete system behavior, the developed prototype models have been interfaced to Lab VIEW software module with laser displacement pickup. The details of the key design features and test results were presented. The pressure control regulator controls the friction load coming to the damper is considered in the present model. The non-linearity behavior of the friction pads and pressure developed at the axial hole on the piston for different loads are investigated.

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