Analysis and Experimental Study of Magnetorheological-Based Damper for Semiactive Suspension System Using Fuzzy Hybrids

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Abstract—In this paper, the development and implementation of a novel semiactive suspension control of a quarter-car model using a hybrid-fuzzy-logic-based controller have been done. The proposed quarter-car model can be described as a nonlinear two-degree-of-freedom system, which is subject to system disturbances from different road profiles. In order to implement the suspension system experimentally, the magnetorheological (MR) fluid has been used as an adjustable damper. The MR damper is a control device that consists of a hydraulic cylinder filled with magnetically polarizable particles suspended in a liquid. The MR damper rapidly dissipates vibration by absorbing energy. In this paper, proportional–integral–derivative (PID), fuzzy logic, and hybrid controllers are used to control the semiactive car suspension system. The results show that both fuzzy logic and hybrid controllers are quite suitable to eliminate road disturbances for the semiactive suspension system considerably as compared to the conventional PID controller.

Index Terms—Fuzzy controller, magnetorheological (MR) damper, quarter-car model, semiactive suspension system.

I. INTRODUCTION

A PASSIVE suspension system of an automobile consists of a spring and a fixed damper unit [1]–[3]. However, in semiactive suspension, the value of the damper coefficient can be controlled and can show reasonable performance as compared to that of an active suspension control. Furthermore, it does not require external energy. Semiactive dampers change their damping force in real time according to the controller requirement, which is usually based on the system dynamics. The ability to vary the semiactive damping coefficient, which is independent of damper velocity within limits, has prompted many researchers to explore the possibility of improving the suspension performance by using semiactive damper technology.

To implement the relevant control law, the semiactive damper must be adjustable in real time. Currently, semiactive dampers can be adjusted hydraulically or magnetically. The first category uses mechanical valves driven by a solenoid or a stepper motor to control the damper force in the hydraulic damper. In the latter category, the rheological effect of controllable fluids, such as magnetorheological (MR) fluid or electrorheological (ER) fluid, is used to provide adjustable damping forces. Although mechanically controlled dampers have been researched and developed extensively, the rheological controllable dampers have not received significant attention in the recent years.

A semiactive device that is particularly promising for suspension protection is the MR damper. The MR dampers use the MR fluids to produce controllable damper action, and some research on MR fluids deals with characterizing the properties of MR fluids. Lazareva and Shitik studied the properties of the MR fluids that are based on barium and strontium ferrites and iron oxides [4]. The hydraulic fluids using various combinations of the materials and their properties, including the MR effects, were investigated. Aghour et al. studied the effects of components of the MR on sedimentation of the magnetic particles and initial viscosity [5]. In another study, these authors studied the general composition of MR fluids along with the methods that are used to evaluate the performance of the fluids [6]. Carlson et al. studied the advantages of MR over ER fluid devices in areas such as working volume of the fluid, yield strength, and required power [7]. The operational modes of the MR fluid are presented along with the linear fluid damper, the rotary brake, and the vibration damper. Kordonsky developed the concept of MR converter (or valve) and applies the MR converter to create devices such as the MR linear damper, the MR actuator, and the MR seal [9]. Finally, Bolter and Janocha examined the rules that should be applied when designing the magnetic circuit for MR devices that are working in different modes of the MR fluid. Bolter and Janocha also examined the use of permanent magnets in the design of the magnetic circuit to change the operational point of the MR device [8]. When a magnetic field is applied to the fluid, particle chains form, and the fluid becomes a semisolid and exhibits viscous-plastic behavior similar to that of the ER fluid. This controllable change of state with some desirable features such as high strength, good stability, broad operational temperature range, and fast response time gives