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SEMI-ACTIVE SECONDARY SUSPENSION CONTROL USING FUZZY SKYHOOK FOR IMPROVING RAILWAY VEHICLE DYNAMICS PERFORMANCE IN LATERAL DIRECTION

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ABSTRACT

In railway vehicle technology, there are continuously increasing requirements regarding riding comfort, running safety, and speed of railway vehicles. These requirements are opposed by the fact that the condition of the tracks is getting worse and maintenance is becoming expensive. In view of this conflict, conventional suspension concepts are unable to accommodate those needs. This paper investigates the performance of semi-active control of lateral suspension system namely fuzzy body-based skyhook and fuzzy bogie-based skyhook for the purpose of attenuating the effects of track irregularities to the body lateral displacement, body roll angle and unwanted yaw responses of railway vehicle. In fuzzy bogie-based skyhook, a virtual damper is attached between bogie and sky to damp out unwanted vibratory motion of the bogie and to prevent the motion to be transmitted to the body. For fuzzy body-based skyhook, the virtual damper is attached between the body and the sky. The controller is optimized on 17-DOF railway vehicle dynamics model and shown 35 % better dynamics performance than its counterparts.

Keywords: railway vehicle, fuzzy body-based skyhook, fuzzy bogie-based skyhook.

INTRODUCTION

The vibration control of the car bodies of railway vehicles is important in improving the ride comfort and safety of trains. There are many types of suspension systems connecting the bogies and the car bodies of railway vehicles have been designed to prevent the passengers from vibrations. Basically, the suspension systems used in railway vehicles can be categorized as passive, active, and semi-active types. Passive suspension systems for railway vehicles using springs and pneumatic or oil dampers have some advantages such as the simple design and cost-effectiveness. Nevertheless, the performances due to the wide frequency range of excitations encouraged by the rail track irregularities may be limited. Because of that, the active suspension technologies for railway vehicles, which utilize oil cylinders and pneumatic actuators, have been proposed and investigated by many researchers (Goodall *et al*., 2002), (Peiffer *et al*., 2005).

An electronically controlled suspension system consists of actuators, sensors and a specific control law, which generates the force demand for the actuator. The actuator should be able to generate the demanded control force in attenuating unwanted vehicle body motions. The effectiveness of control force in attenuating unwanted vehicle body motions depends on the characteristics of the actuator. There are various types of actuators that can be applied in railway vehicles, such as electro-mechanical, electro-magnetic, hydraulic, servo-pneumatic and rheological (electrical or magnetic) systems. An appropriate control strategy has to be chosen together with the actuator. One of the most implemented and analyzed suspension control strategy during the years is skyhook.

In automotive systems, the skyhook principle for the semi-active suspension control has been widely investigated (Nguyen *et al*., 2009), (Chen, 2009), (Savaresi *et al*., 2009), (He *et al*., 2010). The principle involves applying a force through the actuators installed between the car body and the wheel. This force corresponds to the force of a damper for the car body and wheel acting against the inertial frame (Karnopp, 1990). Like most other methods of comfort improvement, the skyhook principle in railway vehicle sets its focus on the reduction of the effects of external disturbance due to track irregularities.

This paper is organized as follows: the first section presents introduction and review of some related works, the second section introduces the proposed control structure for the semi-active lateral suspension system. The third section introduces the proposed disturbance rejection control using fuzzy body-based skyhook and fuzzy bogie-based skyhook. The improvements on railway vehicle dynamics performance in terms of reducing body roll angle, unwanted yaw and unwanted lateral displacement responses using the proposed control strategy are presented in the fourth section. Finally, the last section presents some conclusions.

CONTROL STRUCTURE OF SEMI-ACTIVE SUSPENSION SYSTEM FOR RAILWAY VEHICLE

The controller structure implemented in this study is shown in Figure-1 which consists of two loops