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Designing a sliding mode controller for slip control of antilock brake systems

A. Harifi, A. Aghagolzadeh *, G. Alizadeh, M. Sadeghi

Faculty of Electrical and Computer Engineering, University of Tabriz, Tabriz 51664, Iran

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Abstract

Antilock brake system (ABS) has been designed to achieve maximum negative acceleration by preventing the wheels from locking. Research shows that the friction between road and tire is a nonlinear function of wheel slip. Therefore, maximum negative acceleration can be achieved by designing a suitable control system for wheel slip regulation at its optimum value. Since there is a lot of nonlinearity and uncertainty (uncertainty in mass and center of gravity of the vehicle and road condition) in vehicle dynamics, a robust control method should be used. In this research, a sliding mode controller for wheel slip control has been designed based on a two-axle vehicle model. Important considered parameters for vehicle dynamic include two separated brake torques for front and rear wheels as well as longitudinal weight transfer caused by the acceleration or deceleration. One of the common problems in sliding mode control is chattering phenomenon. In this paper, primary controller design has been improved using integral switching surface to reduce chattering effects. Simulation results show the success of integral switching surface in elimination of chattering side effects and by high performance of this controller. At the end, the performance of the designed controller has been compared with three of the prevalent papers results to determine the performance of sliding mode control integrated with integral switching surface.

Keywords: Antilock brake system; Integral switching surface; Sliding mode control

1. Introduction

Antilock Brake System is one of the most important systems which is used in vehicles nowadays to improve the safety of the driver and passengers. The main idea of ABS is to attain the optimum negative acceleration rate without sacrificing the stability and steering ability of the vehicle (Kueon and Bedi, 1995).

When a vehicle is braking or accelerating, the tractive forces produced by the tire are proportional to the normal forces of the road acting on the tire. The coefficient of this proportion, denoted μ, is called road coefficient of adhesion (or friction coefficient) and varies depending on the road surface. Researches show that the road coefficient of adhesion is a nonlinear function of wheel slip (λ) in a specified road condition (Fig. 1).

* Corresponding author. Tel.: +98 411 339 3720; fax: +98 411 3300819.
E-mail addresses: a_harifi@tabrizu.ac.ir (A. Harifi), aghagol@tabrizu.ac.ir (A. Aghagolzadeh).

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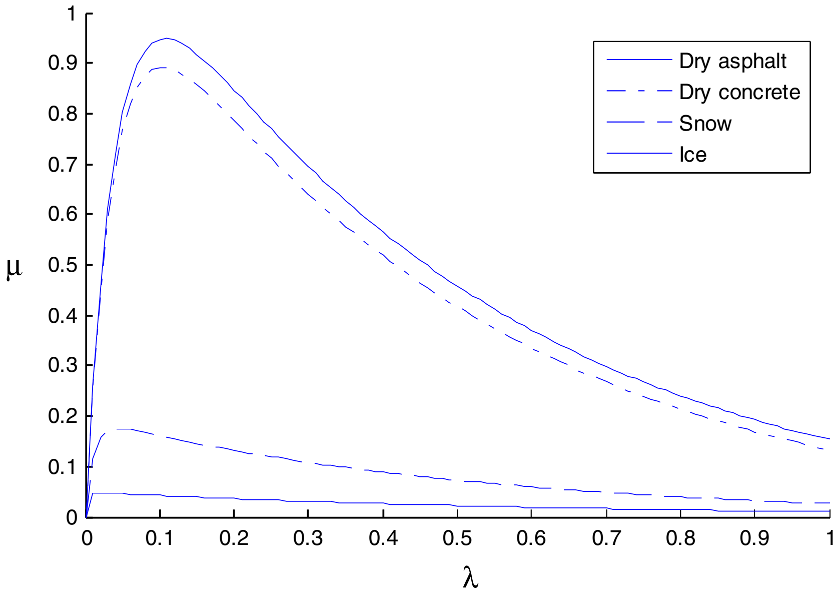

Fig. 1. A typical μ–λ curve.

Therefore the most important goal in designing a controller for ABS is to design a suitable controller which can regulate the real wheel slip at its optimum value.

Antilock brake systems present a challenging control problem because (Akbarzadeh et al., 2002):

1. vehicle model dynamics are highly nonlinear;
2. controller must operate at unstable equilibrium point for optimal performance;
3. model parameters vary over a wide range due to variations of road and vehicle conditions such as road surface, mass and center of gravity of the vehicle;
4. sensor signals are highly uncertain as noisy.

Therefore, it seems that a robust controller should be used for solving these control problems. The sliding mode control is a common robust control method. Hence a lot of researches are based on the sliding mode control method (Chin et al., 1992; Drakunov et al., 1995; Lin and Hsu, 2003a, 2003b; Ming, 1997; Tan and Tomizuka, 1989; Unsal and Kachroo, 1999).

Lin and Hsu used a neural network estimator to estimate the uncertainty of the system to reduce chattering phenomena which is produced by sliding mode control (Lin and Hsu, 2003a).

In another paper, Lin and Hsu introduced a fuzzy controller combined with sliding mode control to reduce the dependency of controller on vehicle model (Lin and Hsu, 2003b).

Unsal and Kachroo have used sliding mode control to regulate wheel slip at its optimum value too. In their paper, a PI-like controller was used near the switching surface instead of sign function to reduce chattering (Unsal and Kachroo, 1999).

In this paper, the control strategy is sliding mode control too. But unlike other papers, the controller has been designed based on a two-axle vehicle model. Important considered parameters for vehicle dynamic include two separated brake torques for front and rear wheels as well as longitudinal weight transfer caused by the acceleration or deceleration. Then the primary controller design has been improved using integral switching surface to reduce chattering phenomena. At the end, the desired controller has been compared with the controllers introduced in Lee and Zak (2002) and Lin and Hsu (2003a,b). Simulation results show the success of integral switching surface in significant reduction of chattering and high performance of this controller with respect other controllers.