Chapter 1. Introduction

1.1. Motivation

In Automatic highway system, automatic brake actuation is a very important part of the overall vehicle control system. The precise application of brake torque is essential to maintaining proper vehicle spacing (on the order of a meter is maintained during routine merge and following maneuvers) and ride quality on an automatic highway. Due to the nonlinearities of the brake actuation system, a faster response, and robust braking control system is crucial. For emergency maneuver requirement, the precise application of brake torque is crucial for avoiding the wheel lock-up. By having electromagnetic brake as a supplementary retardation system, we can provide better response time for emergency situations and in general keep the whole brake system working longer and safer.

The principle of braking in road vehicles involves the conversion of kinetic energy into heat. This high energy conversion therefore demands an appropriate rate of heat dissipation if a reasonable temperature and performance stability are to be maintained. While the design, construction, and location features severely limit the heat dissipation function of the friction brakes, electromagnetic brakes work in a relatively cool condition and avoid problems that friction brakes face by using a totally different working principle and installation location. Electromagnetic brakes have better capability of heat dissipation and work independently by itself without increasing the temperature of the regular friction brakes. By using the electromagnetic brake as supplementary retardation equipment, the friction brakes can be used less
frequently and therefore practically never reach high temperatures. The brake linings thus have a longer life span, and the potential “brake fade” problem can be avoided. It is apparent that the electromagnetic brake is an essential complement to the safe braking of heavy vehicles.

Therefore, it is a growing area of interest to evaluate, simulate and implement the electromagnetic brakes and its control system.

1.2. Outline of the study

In this study, a new mathematical model for electromagnetic brakes is proposed to describe their static characteristics (angular speed versus brake torque). A software program written in Matlab® can be used to code different brake characteristics (both static and dynamic) and evaluate their performance in different road scenarios.

A controller is designed that achieves wheel-slip control for vehicle motion. The objective of this brake control system is to keep the wheel slip at an ideal value so that the tire can still generate lateral and steering forces as well as shorter stopping distances. In order to control the wheel slip, vehicle system dynamic equations are given in terms of wheel slip. The system shows the nonlinearities and uncertainties (both uncertainty of the parameters and unmodeled system dynamics). Hence, a nonlinear control strategy based on sliding mode, which is a standard approach to tackle the parametric and modeling uncertainties of a nonlinear system, is chosen for slip control. Due to its robustness properties, the sliding mode controller can solve two major difficulties involved in the design of a braking control algorithm:

1) the vehicle system is highly nonlinear with time-varying parameters and uncertainties;
2) the performance of the system depends strongly on the knowledge of the tire/road surface condition.
A nominal vehicle system model is simulated in software and a sliding mode controller would be designed to maintain the wheel slip at a given value (range) under different road conditions. The vehicle is decelerated by the friction force between tire and road. The shape of friction coefficients between tire and road has been known to reach a maximum within 10% to 20% slip range. The friction values decrease with an increase in slip after that range. At wheel lockup (100% slip), the value of the friction coefficient may decrease 40% compared with the friction maximum. These phenomena are the major motivation of designing an anti-lock braking system to achieve the maximum friction force on the vehicle.

Microcontroller implementation of the anti-lock braking systems also will be studied. The specific microcontroller used in the Center for Transportation Research is the Motorola 68HC11 series. Evaluation will be performed to explore the suitability of 68HC11 application on anti-lock brake system.

It is hoped that this study provides some insight and ideas for future efforts.