

STUDY OF MODELLING & DEVELOPMENT OF ANTILOCK BRAKING SYSTEM

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ABSTARCT

Antiknock braking systems are used in modern cars to prevent the wheels from locking after brakes are applied. The dynamics of the controller needed for antiknock braking system depends on various factors. The vehicle model often is in nonlinear form. Controller demand to provide a controlled torque necessary to maintain optimum value of the wheel slip ratio. The slip ratio is represented in terms of vehicle velocity and wheel rotation. In present work first of all system dynamic equations are explained and a slip ratio is expressed in terms of system variables namely vehicle linear velocity and angular speed of the wheel. By exempt a bias braking force system, response is obtained using Simulation models. Using the linear control strategies like P - type, PD - type, PI - type, POD - type the effectiveness of maintaining desired slip ratio is tested. It is always looked that a steady state error of 10% occurring in all the control system models.

I. INTRODUCTION

Anti-lock brake systems (ABS) prevent brakes from locking during braking. Under normal braking conditions the driver controls the brakes. However, during severe braking or on slippery roadways, when the driver causes the wheels to approach lockup, the antilock system takes over. ABS modulates the brake line pressure independent of the pedal force, to bring the wheel speed back to the slip level range that is necessary for optimal braking performance. An antilock system consists of wheel speed sensors, a hydraulic modulator, and an electronic control unit. The ABS has a feedback control system that modulates the brake pressure in response to wheel deceleration and wheel angular velocity to prevent the controlled wheel from locking. The system shuts down when the vehicle speed is below a pre-set threshold.

1.1 Importance Of Antilock Braking Systems

The objectives of antilock systems are threefold:

1. to reduce stopping distances,
2. to improve stability, and
3. to improve steerability during braking.

These are explained below

• Stopping Distance

The distance to stop is a function of the mass of the vehicle, the initial velocity, and the braking force. By maximizing the braking force the stopping distance will be minimized if all other factors remain constant. However, on all types of surfaces, to a greater or lesser extent, there exists a peak in friction coefficient. It follows that by keeping all of the wheels of a vehicle near the peak, an antilock system can attain maximum

fictional force and, therefore, minimum stopping distance. This objective of antilock systems however, is tempered by the need for vehicle stability and steerability.

- **Stability**

Although decelerating and stopping vehicles constitutes a fundamental purpose of braking systems, maximum friction force may not be desirable in all cases, for example not if the vehicle is on a so-called p-split surface (asphalt and ice, for example), such that significantly more braking force is obtainable on one side of the vehicle than on the other side. Applying maximum braking force on both sides will result in a yaw moment that will tend to pull the vehicle to the high friction side and contribute to vehicle instability, and forces the operator to make excessive steering corrections to counteract the yaw moment. If an antilock system can maintain the slip of both rear wheels at the level where the lower of the two friction coefficients peaks, then lateral force is reasonably high, though not maximized. This contributes to stability and is an objective of antilock systems.

- **Steerability**

Good peak frictional force control is necessary in order to achieve satisfactory lateral forces and, therefore, satisfactory steerability. Steerability while braking is important not only for minor course corrections but also for the possibility of steering around an obstacle. Tire characteristics play an important role in the braking and steering response of a vehicle. For ABS-equipped vehicles the tire performance is of critical significance. All braking and steering forces must be generated within the small tire contact patch between the vehicle and the road. Tire traction forces as well as side forces can only be produced when a difference exists between the speed of the tire circumference and the speed of the vehicle relative to the road surface. This difference is denoted as slip. It is common to relate the tire braking force to the tire braking slip. After the peak value has been reached, increased tire slip causes reduction of tire-road friction coefficient. ABS has to limit the slip to values below the peakvalue to prevent wheel from locking. Tires with a high peak friction point achieve maximum friction at 10 to 20% slip. The optimum slip value decreases as tire-road friction decreases.

The ABS system consists of the following major subsystems.

- **Wheel-Speed Sensors**

Electro-magnetic or Hall-effect pulse pickups with toothed wheels mounted directly on the rotating components of the drivetrain or wheel hubs. As the wheel turns the toothed wheel (pulse ring) generates an AC voltage at the wheel-speed sensor. The voltage frequency is directly proportional to the wheel's rotational speed.

- **Electronic Control Unit (ECU)**

The electronic control unit receives, amplifies and filters the sensor signals for calculating the wheel rotational speed and acceleration. This unit also uses the speeds of two diagonally opposed wheels to calculate an estimate for the speed of the vehicle. The slip at each wheel is derived by comparing this reference speed with the speeds of the individual wheels. The "wheel acceleration" and "wheel slip" signals serve to alert the ECU to any locking tendency. The microcomputers respond to such an alert by sending a signal to trigger the pressure control valve solenoids of the pressure modulator to modulate the brake pressure in the individual wheel-brake cylinders. The ECU also incorporates a number of features for error recognition for the entire ABS system (wheel-speed sensors, the ECU itself, pressure-control valves, wiring harness). The ECU reacts to a recognized defect or error by switching off the malfunctioning part of the system or shutting down the entire ABS.

- **Hydraulic Pressure Modulator**

The hydraulic pressure modulator is an electro-hydraulic device for reducing, holding, and restoring the pressure of the wheel brakes by manipulating the solenoid valves in the hydraulic brake system. It forms the hydraulic link between the brake master cylinder and the wheel-brake cylinders. The hydraulic modulator is mounted in the engine compartment to minimize the length of the lines to the brake master cylinder and the wheel-brake cylinders. Depending on the design, this device may include a pump, motor assembly, accumulator and reservoir.

1.2 Literature Review

Following literature is surveyed relating to ABS.

Mirzaeinejad and Mirzaei [1] have applied a predictive approach to design a non-linear model-based controller for the wheel slip. The integral feedback technique is also employed to increase the robustness of the designed controller. Therefore, the control law is developed by minimizing the difference between the predicted and desired responses of the wheel slip and its integral. Baslamisli *et al.* [2] proposed a static-state feedback control algorithm for ABS control. The robustness of the controller against model uncertainties such as tire longitudinal force and road adhesion coefficient has been guaranteed through the satisfaction of a set of linear matrix inequalities. Robustness of the controller against actuator time delays along with a method for tuning controller gains has been addressed. Further tuning strategies have been given through a general robustness analysis, where especially the design conflict imposed by noise rejection and actuator time delay has been addressed.

Choi [3] has developed a new continuous wheel slip ABS algorithm. here ABS algorithm, rule-based control of wheel velocity is reduced to the minimum. Rear wheels cycles independently through pressure apply, hold, and dump modes, but the cycling is done by continuous feedback control. While cycling rear wheel speeds, the wheel peak slips that maximize tire-to-road friction are estimated. From the estimated peak slips, reference velocities of front wheels are calculated. The front wheels are controlled continuously to track the reference velocities. By the continuous tracking control of front wheels without cycling, braking performance is maximized. Rangelov [4] described the model of a quarter-vehicle and an ABS in MATLAB-SIMULINK. In this report, to model the tire characteristics and the dynamic behavior on a flat as well as an uneven road, the SWIFT-tire model is employed. Sharkawy [5] studied the performance of ABS with variation of weight, friction coefficient of road, road inclination etc. A self-tuning PID control scheme to overcome these effects via fuzzy GA is developed; with a control objective to minimize stopping distance while keeping slip ratio of the tires within the desired range. Poursmad [6] has proposed an adaptive NN-based controller for ABS. The proposed controller is designed to tackle the drawbacks of feedback linearization controller for ABS. Topalov *et al.* [7] proposed a neurofuzzy adaptive control approach for nonlinear system with model uncertainties, in antilock braking systems. The control scheme consists of PD controller and an inverse reference model of the response of controlled system. Its output is used as an error signal by an online algorithm to update the parameters of a neuro-fuzzy feedback controller. Patil and Longoria [8] have used decoupling feature in frictional disk brake mechanism derived through kinematic analysis of ABS to specify reference braking torque is presented. Modelling of ABS actuator and control design are described. Layne *et al.* [9] have illustrated the fuzzy model reference learning control (FMRLC). Braking effectiveness when there are transition between icy and wet road surfaces is studied. Huang and Shih [10] have used the fuzzy controller to control the hydraulic modulator and

hence the brake pressure. The performance of controller and hydraulic modulator are assessed by the hardware in loop (HIL) experiments. Onit et al. [11] have proposed a novel strategy for the design of sliding mode controller (SMC). As velocity of the vehicle changes, the optimum value of the wheel slip will also alter. Gray predictor is employed to anticipate the future output of the system.

1.3 Scope & Objective Of Present Work

During the design of ABS, nonlinear vehicle dynamics and unknown environment characters as well as parameters, change due to mechanical wear have to be considered. PID controller are very easy to understand and easy to implement. However PID loop require continuous monitoring and adjustments. In this line there is a scope to understand improved PID controllers with mathematical models.

The present work, it is planned to understand and obtain the dynamic solution of quarter car vehicle model to obtain the time varying vehicle velocity and wheel. After identification of system dynamics a slip factor defined at each instance of time will be modified to desired value by means of a control scheme. Various feedback control schemes can be used for this purpose. Simulation are carried out to achieve a desired slip factor with different control scheme such as

- 1) Proportional Feedback control
- 2) Proportional Derivative Feedback Control
- 3) Proportional Integral Feedback Control
- 4) Proportional Integral Derivative Feedback Control

Graphs of linear velocity, stopping distance and slip ratio for each system is plotted and compared with each other. At the end, possible alternate solutions are discussed.

The work is inspired from the demo model of ABS provided in Simulink software.

1.4 Organisation Of Thesis

Chapter 2 describes the mathematical modelling of quarter vehicle and vehicle dynamic equations used to describe the system. Feedback control systems which are used for ABS are explained. Simulink Models of each control system are described. Chapter 3 contains various graphs obtained from each of Simulink models. Comparison and discussion between different control schemes are shown. Chapter 4 concludes the above work. It contains summary of work and throws light on future scope for further studies and development.

II. MATHEMATICAL MODELLING

2.1 Vehicle Dynamics

Basically, a complete vehicle model that includes all relevant characteristics of the vehicle is too complicated for use in the control system design. Therefore, for simplification a model capturing the essential features of the vehicle system has to be employed for the controller design. The design considered here belongs to a quarter vehicle model as shown in Fig 2.1. This model has been already used to design the controller for ABS.

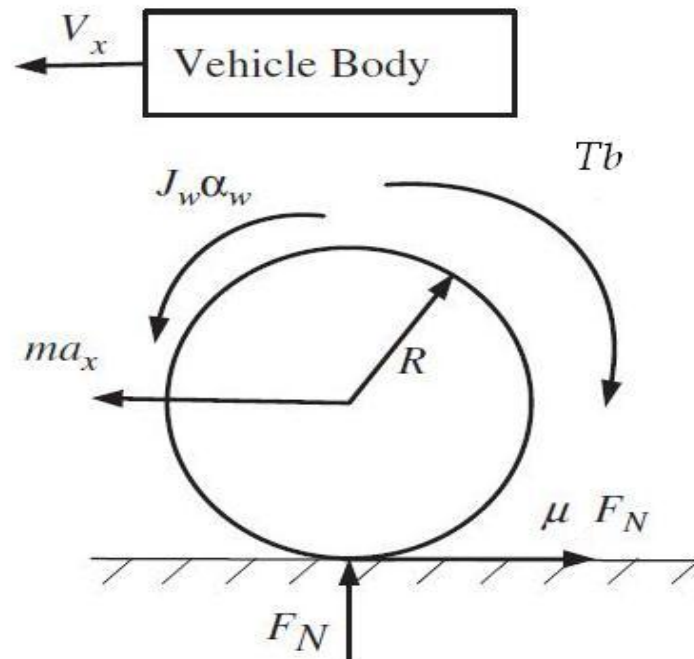


Fig 2.1 Quarter Vehicle Model

III. CONCLUSION

In this thesis an attempt is made to grasp the application of various type of linear controller used for anti-lock braking systems. The system was modeled with a one fourth vehicle dynamics and differential equation of motion was formulated. The slip ratio is used contain as a criterion for this control work. Friction force and normal reaction are intention of slip ratio and in turn entire equations were nonlinear. The second order differential equations were written as three state space equations (1st order equations) and solutions are obtained by time integration method and are directly achieved with MAZATLAN Simulation block diagrams. The time histories of the wheel, stopping distance of the vehicle, and slip factor divergences are obtained for benchmark problem available in literature. Various central strategies like P-type, PD-type, PI-type, and PID-type have been implemented to augment the constant braking torque so as to control the slip ratio.

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