Car Wheel slip Modelling, Simulation, and Control using Quarter Car Model

Abubaker Abasalam A. Emheisen[1], Abdussalam Ali Ahmed[2], Nasr Ismael Alhusein[3], Abdurahim Alfadel Sakeb[4], Abdulhamid.S. Abdulhamid[5]

[1,2,3,4]*Faculty of Engineering, Azzaytuna University/ Libya*
[5]*College of Electronic technology, Bani Walid / Libya*

Abstract* — This paper presents a Simulink model of a car wheel slip control loop as might be used in a rudimentary ABS system. Although idealized equations are used, the overall model demonstrates many of the essential features of a Simulink model. Each of the individual components in the loop are discussed separately: a tire model; a quarter car model; a brake actuator; and a (PI) controller. The model for each component demonstrates a different feature of Simulink: the tire model shows how to implement a simple equation; the quarter car model shows how to implement non-linear continuous time equations; the actuator model illustrates how to handle time delays; while the controller shows how to implement discrete time difference equations. Since the quarter car model and actuator are modelled in continuous time, while the controller is implemented in discrete time, the developed model is also excellent example of how to implement hybrid continuous-discrete systems within Simulink.

Keywords — *Quarter car model, Wheel slip, PI controller, Pacejk magic formula, Simulink model.*

I. INTRODUCTION

Traction control method is paramount to car safety in slippery road conditions. Observing wheel slip is the first step in creating a system that controls in real time or prevents large differences between car and wheel velocity. An active slip control would not only benefit safety, but also reduce costs of maintenance by reducing rubber ware. A system that is able to control wheel speed is also applicable in braking, as an antilocking system. Wheel speed estimation is not an issue; an encoder can precisely read the position. car speed, however, is proving to be a big challenge. A free wheel with an encoder reading the velocity values would be a simple solution, except in the case when breaking is done at that wheel. Using an accelerometer would seem like an alternative, but as will be presented, it is not the simplest solution, nor is it the most precise in itself. It raises a number of issues including computational needs and reliability. Wheel slip is measured experimentally using a vehicle prototype. Current technologies are optimized for use on conventional Ackerman steering[Daniel SZÖCS,2012], petrol based vehicles. Slipping is controlled by varying brake force, thus affecting the vehicle speed parameter. Other methods include active torque distribution, like the ones used in four-wheel drive transmission systems. The advantage of individual torque control is that adhesion to the surface is distributed accordingly to the individual wheel and road slip coefficient. This way, slip control can be achieved quicker, more precisely and in some cases without the need for mathematical computation. When cornering, torque can be electronically controlled so that the outer wheels don't lose traction and allows for high speed cornering.

II. MATERIALS AND METHODS

The study aims to modelling, simulation, and control of car wheel slip using Matlab. The analysis of this study needs some steps to obtain how to control in wheel slip using quarter car model .

The tire model implemented in this study uses the standard Pacejk magic formula and PI controller (Here a simple PI (proportional–integral) controller has been shown to be adequate.

III. THE QUARTER CAR MODEL:

This work uses a standard set of equations for the dynamics of a quarter car which shown in figure 1. It contains two continuous time states, and is described by the set of non-linear equations.

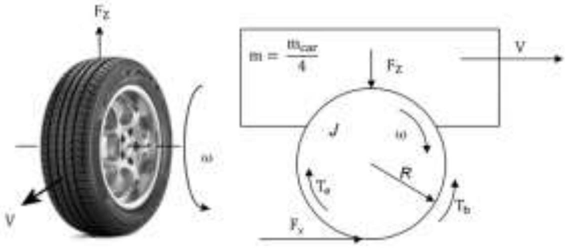


Fig.1 Quarter car model.

$$J\dot{\omega} = RF_x - sign(\omega)T_b$$
$$m\dot{v} = -F_x$$
$$\lambda = \frac{v - R\omega}{v}$$
$$F_x = F_z\mu_x$$
$$F_z = mg$$

where ω > 0, ν > 0, and hence -1 < λ < 1.

The following table lists the definition of the notation used in above equations.

TABLE 1.
QUARTER CAR MODEL PARAMETERS

Name	Description	Value
ω	Angular Speed	Output Signal
v	Longitudinal velocity	Output Signal
J	Inertia	1 Kg m^2
R	Wheel Radius	0.32 m
T_b	Brake Torque	Input Signal
F_x	Longitudinal Force	Calculated
λ	Longitudinal Wheel Slip	Calculated
F_z	Vertical Force	Calculated
μ_x	Road Friction Coefficient	Calculated
m	Quarter Vehicle Mass	450 Kg
g	Gravitational Force	9.81 ms^{-2}

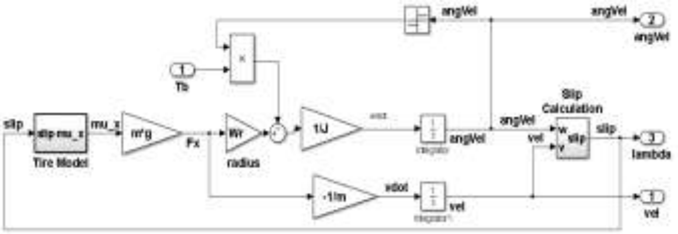


Figure 2 below is the simulink model of the qurter car model which built based on above equateions.

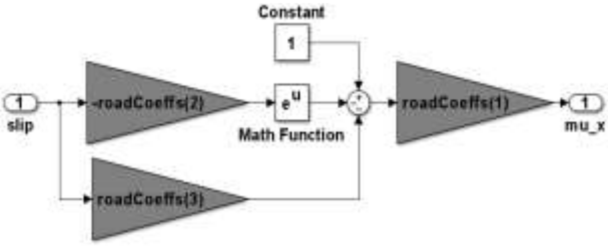
Fig .2 $\mu_x = a\left(1 - e^{-b\lambda} - c\lambda\right)$ Quarter Car Model Simulink model.

IV..THE TIRE MODEL:

The tire model used in this work uses the standard Pacejk magic formula. In Pacejk's model, the equation for the longitudinal friction coefficient μx is given

where λ is the wheel slip, and the coefficients a, b and c change depending on the current road surface. This example assumes that the vehicle is being driven on dry asphalt and hence the coefficients are a = 1.28, b = 23.99 and c = 0.52.figure 3 shows The Matlab Simulink model for the tire model when using of Pacejk magic formula .

Fig. 3 Tire Model Simulink subsystem.



V. THE ACTUATOR MODEL AND THE CONTROLLER MODEL:

Actuator dynamics, and particular time delays, are often critical to the design of a sufficiently accurate control algorithm. In this paper a simple first order lag in series with a time delay to model the actuator used.

Also in this work, a simple PI (proportional–integral) controller has been shown to be adequate.

Figure 4 shows the Simulink models of each of the actuator and the controller.

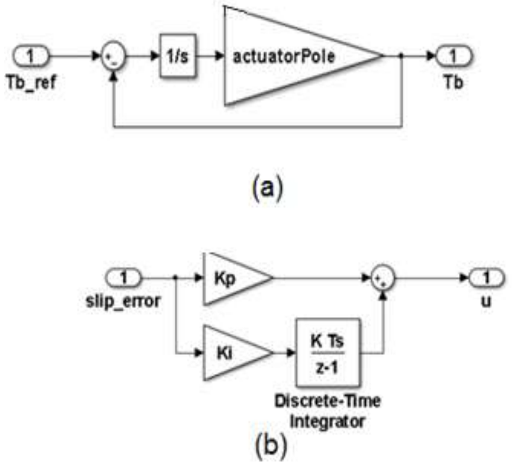
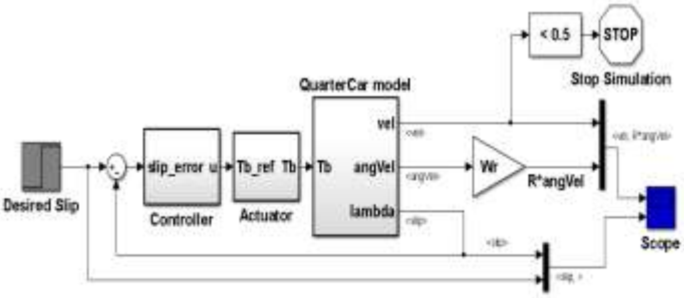


Fig .4 (a) the actuator model (b) the PI controller model.

VI. OVERVIEW OF THE COMPLETE MODEL:

Figure 5 shows the control loop used in this paper . The controller, actuator and quarter car models are all in the feed forward path. The calculated wheel slip (which is to be controlled) is fed back and compared to a desired slip value, with the error fed into the controller.

Fig .5 Simulink Model Of Quarter Car Wheel Slip Control Loop.



VII. SIMULATION RESULTS AND DISCUSSION

The blue line in Figure 6 shows the vehicle longitudinal velocity and the magenta line shows the wheel's linear velocity (calculated as the wheel radius multiplied by the angular velocity). When there is no wheel slip the two lines are the same. When the magenta line is below the blue line there is wheel slip.

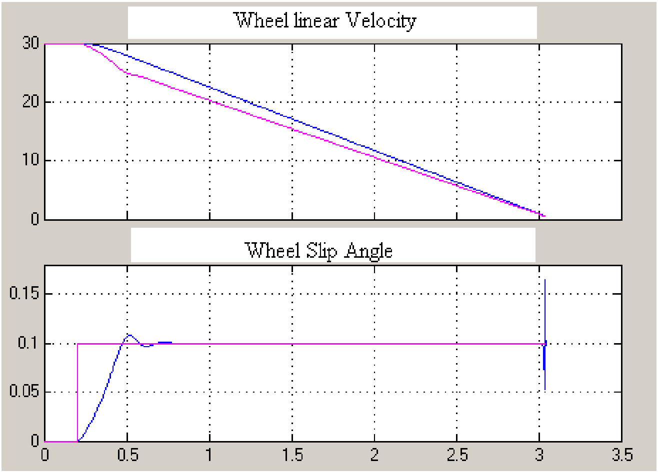


Fig .6 Simulink model results.

VIII. CONCLUSION

This study shows how to simple Matlab Simulink model used to control in wheel slip of a car. Quarter car model used in this work and the standard Pacejk magic formula. Also, actuator dynamics took into account. This paper demonstrated that the vehicle is moving with velocity at 30m/s with no wheel slip. At T=0.2s a slip of $\lambda = 10$ percent is demanded, which is achieved by applying the brake to the wheel. Consequently the vehicle decelerates reducing its velocity to become zero. The controller has the desired effect which is to track the demanded slip at the required value of 10 percent. It takes about 0.2s to achieved this level of slip, which in some

applications may be too slow. In that case the controller could be redesigned to try to achieve good tracking.

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