International Journal on Emerging Trends in Mechanical & Production Engineering
Vol. 1, Issue 1 - 2017

COMPARISION OF VEHICLE PERFORMANCE WITH & WITHOUT ANTI-LOCK BRAKING SYSTEM

SATYA BRAMHA[*], RAVI TEJA[*]

ABSTRACT

An Antilock Brake System (ABS) is a closed loop control system that modulates the brake torque that is applied to the wheel in order to prevent the controlled wheel from becoming fully locked. ABS is among the most important safety systems in a vehicle. In automatic highway system, automatic brake actuation is a very important part of the overall vehicle control system. It prevents the wheel lock-up under critical braking conditions, such as those encountered with wet or slippery road surfaces and driver panic reaction (Bosch, 1995). By preventing the wheel lock-up, ABS ensures that the vehicle remains responsive to steering wheel inputs. Reduced stopping distance on account of ABS is more evident on wet or slippery road surfaces (Garrick *et al*., 1998).

This paper describe the implementation of Antilock Braking System using MATLAB/ Simulink, & than the comparison of vehicle performance with & without anti-lock braking system

KEYWORDS: Antilock Braking Systems (ABS), Matlab/ Simulink, Passenger Safety, Engine Control Unit.

INTRODUCTION

Antilock Braking Systems (ABS) is closed loop control devices within the braking systems which prevent the wheel lock-up during braking and as a result, retain vehicle steer ability and stability.

The main ABS components are hydraulic modulators, wheel speed sensors, ECU for signal processing and control and triggering of the signal lamp and of the actuators in the hydraulic modulator.

[*]Students, Engineering and Technology, Manav Rachna International University, Faridabad.
Correspondence E-mail Id: editor@eurekajournals.com

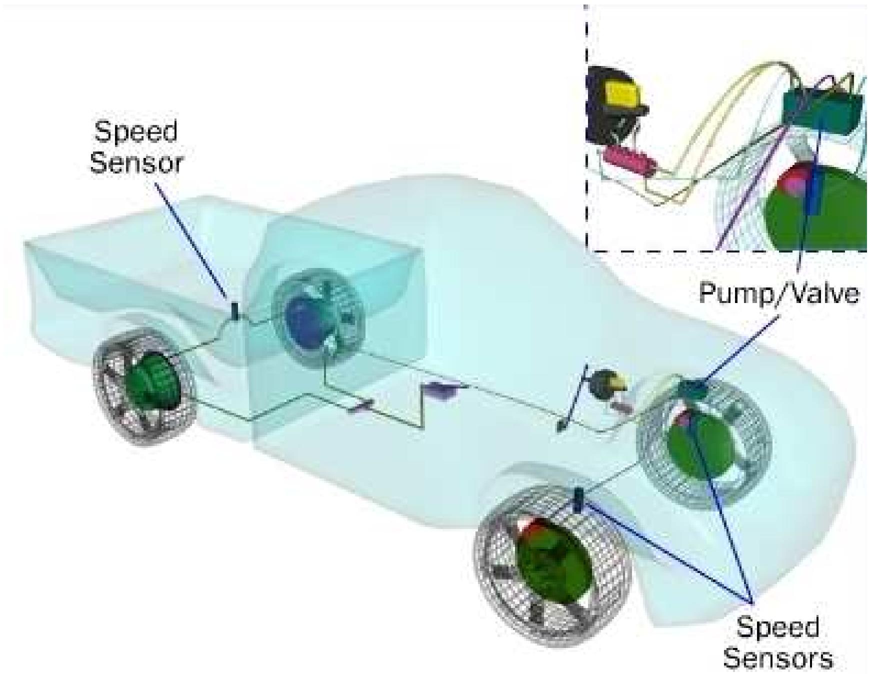

Figure 1.Location of the ABS in a vehicle

BLOCK DIAGRAM OF ABS

On initial braking, the brake pressure is increased, the brake slip λ rises and at the maximum point on the adhesion/slip curve, it reaches the limit between the stable and unstable ranges. From this point on, any further increase in the brake pressure or braking torque does not cause any further increase in braking force F_B. In the stable range, the brake slip is largely deformation slip, it increasingly tends towards skidding in the unstable range.

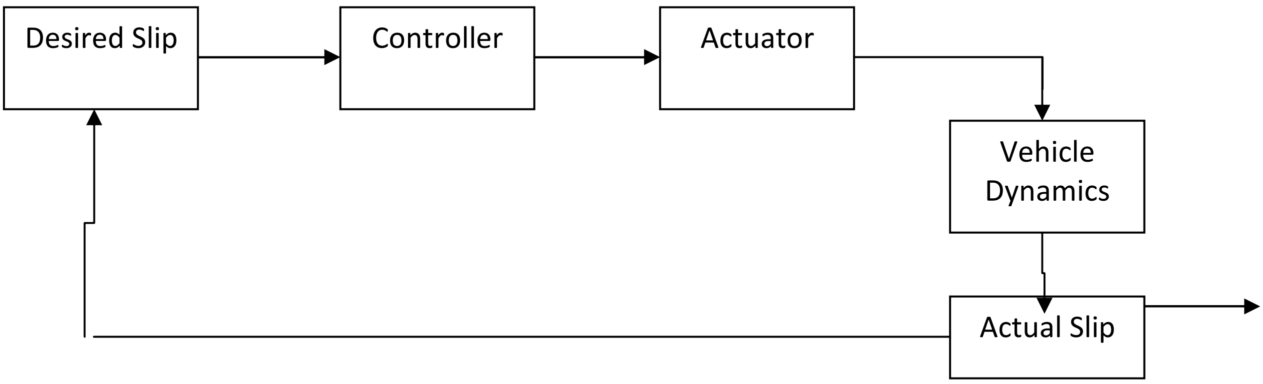

Figure 2.Block Diagram of ABS

We model the ABS using Matlab/ Simulink where in the various mechanical blocks are realized and mathematical models of the same are readily available in the Simulink library. The ABS simulation model follows the below shown control loop. The reference variable is the desired relative slip which is fed as an input to the system. The control system in our case is the wheel whose parameters like wheel speed are measured. The feedback path consists of the user defined equation which measures the relative slip of the wheel and the error is rectified at the initial stage. The model represents a single wheel, which may be replicated a number of times to create a model for a multi-wheel vehicle.

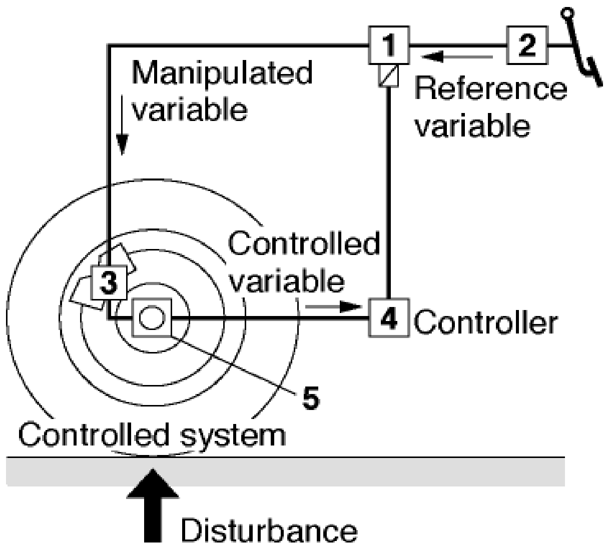

Figure 3.ABS Control Loop

ANALYSIS OF ABS

For understanding the concept of ABS, we make use of the free body diagram of a wheel. We make use of the formulae for force and torque acting on the wheel. The below figure gives us a clear understanding about the forces acting on a wheel. The wheel rotates with an initial angular speed that corresponds to the vehicle speed before the brakes are applied. We used separate integrators to compute wheel angular speed and vehicle speed. We use two speeds to calculate slip, which is determined below. Note that we introduce vehicle speed expressed as an angular velocity (see below).

$\omega_V = \frac{V}{R}$. (Equal to wheel angular speed if there is no slip.) (1)

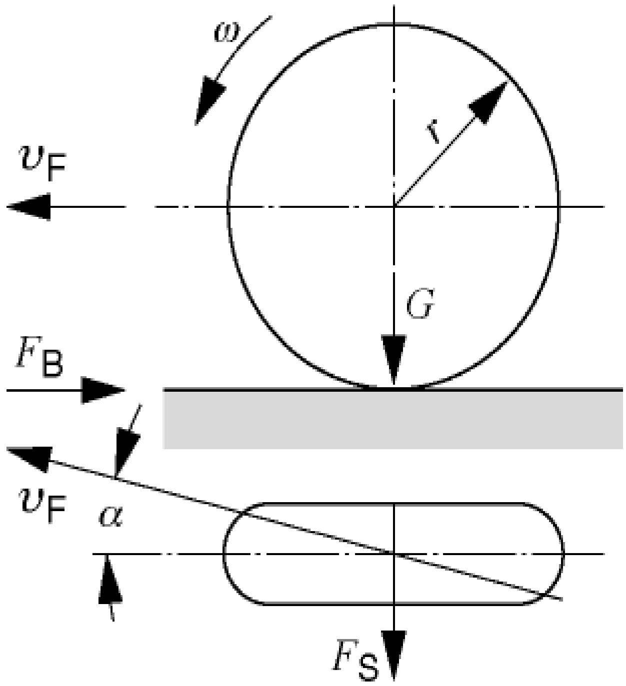

Figure 4.Free Body Diagram of a single wheel

$$\omega_V = \frac{V_v}{R_r} \tag{2}$$

$$slip, \lambda = 1 - \frac{\omega_\omega}{\omega_v} \tag{3}$$

ω_v is the wheel speed divided by the wheel radius.

V_v is the vehicle linear velocity.

R_r is the wheel radius.

ω_ω is the wheel angular velocity.

We can also write (3) as

$$\lambda = \frac{v - \omega r}{v} \tag{4}$$

Where

V is the vehicle speed, ω is the wheel speed and r is the radius of the wheel. From these expressions, we see that slip is zero when wheel speed and vehicle speed are equal, and slip equals one when the wheel is locked. A desirable slip value is 0.2, which means that the number of wheel revolutions equals 0.8 times the number of revolutions under non-braking conditions with the same vehicle velocity. This maximizes the adhesion between the tire and road and minimizes the stopping distance with the available friction.

If an excessive brake torque is applied, the wheel will be locked, which means that it slides on the road surface but does not rotate at all. A locked wheel has no lateral stability and less longitudinal friction force, which is the ultimate force to stop the vehicle. Thus, a braking with a locked wheel will cause longer stopping distance and lateral instability. The tire force from the road surface causes the wheel velocity to increase, thus decreases the wheel slip. A high μ leads to a large tyre force and a low μ leads to a small tyre force. In the increasing part of the μ-slip curve, an increase of the wheel slip leads to a larger μ and a larger tyre force, which reverses the wheel slip to a small value. However, in the decreasing part of the μ-slip curve, an increase of the wheel slip leads to a smaller μ and a smaller tyre force, which causes the wheel slip to increase continuously. So, the peak point of the μ-slip curve is critical.

When a braking is initiated, the wheel velocity starts to decrease and the wheel slip starts to increase from zero. The wheel slip may stop increasing and start to decrease before the μ reaches its peak point. But if an excessive brake torque is applied, the wheel slip may go straightly to a large number, which causes the μ to pass its peak point and reach somewhere in the decreasing part of the μ-slip curve. If the brake torque is not reduced quickly at this point, the reduction of the road friction force will lead to a rapid increase of the wheel slip and eventually to a wheel lockup. ABS tries to detect when this peak point is going to be reached and then reduces the brake torque properly so that a wheel lockup could be avoided.

It appears to be true that maintaining the wheel slip at the peak point of the μ- slip curve is ideal. However, the position of the peak μ point varies on the different road surfaces. In addition, stay at the peak point of the μ- slip curve sometime may lead to a poor lateral stability. Thus, many control strategies define their performance goal as maintaining the wheel slip near a value of 0.2. This represents a compromise between the lateral stability, which is best at λ=0 and the maximum deceleration which usually appears when λ is between 0.1 and 0.3.

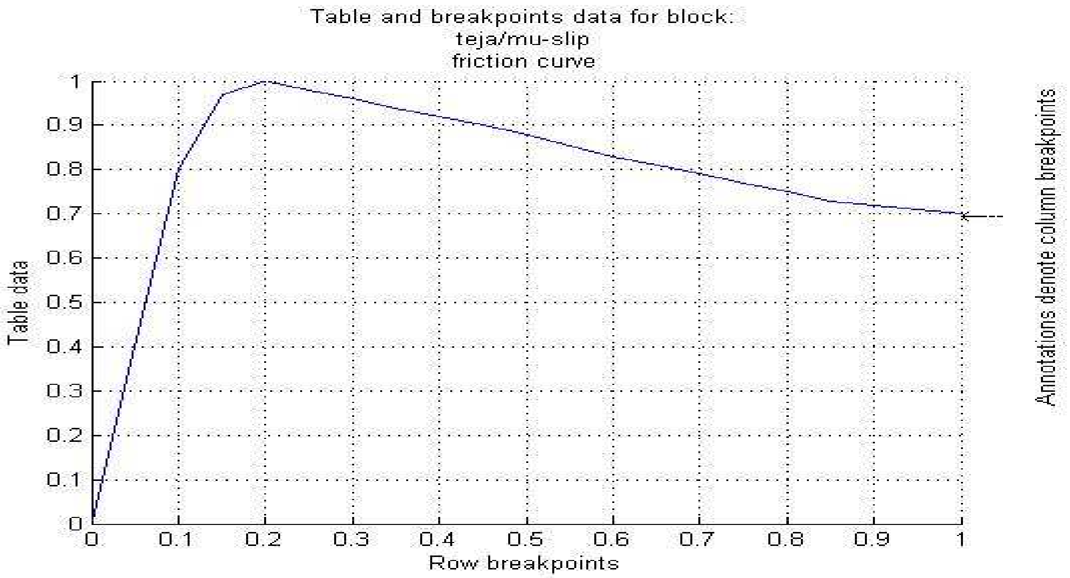

Figure 5.μ-slip Friction Curve

IMPLEMENTATION

The friction coefficient between the tire and the road surface, μ, is an empirical function of slip, known as the μ-slip curve. We created mu-slip curves by passing MATLAB variables into the block diagram using a Simulink lookup table. The model multiplies the friction coefficient, μ, by the weight on the wheel, W, to yield the frictional force, F_f, acting on the circumference of the tire. F_f is divided by the vehicle mass to produce the vehicle deceleration, which the model integrates to obtain vehicle velocity.

In this model, we used an ideal anti-lock braking controller that uses 'bang-bang' control based upon the error between actual slip and desired slip. We set the desired slip to the value of slip at which the μ-slip curve reaches a peak value, this being the optimum value for minimum braking distance (see note below.).

Note: In an actual vehicle, the slip cannot be measured directly, so this control algorithm is not practical. It is used here to illustrate the conceptual construction of a simulation model.

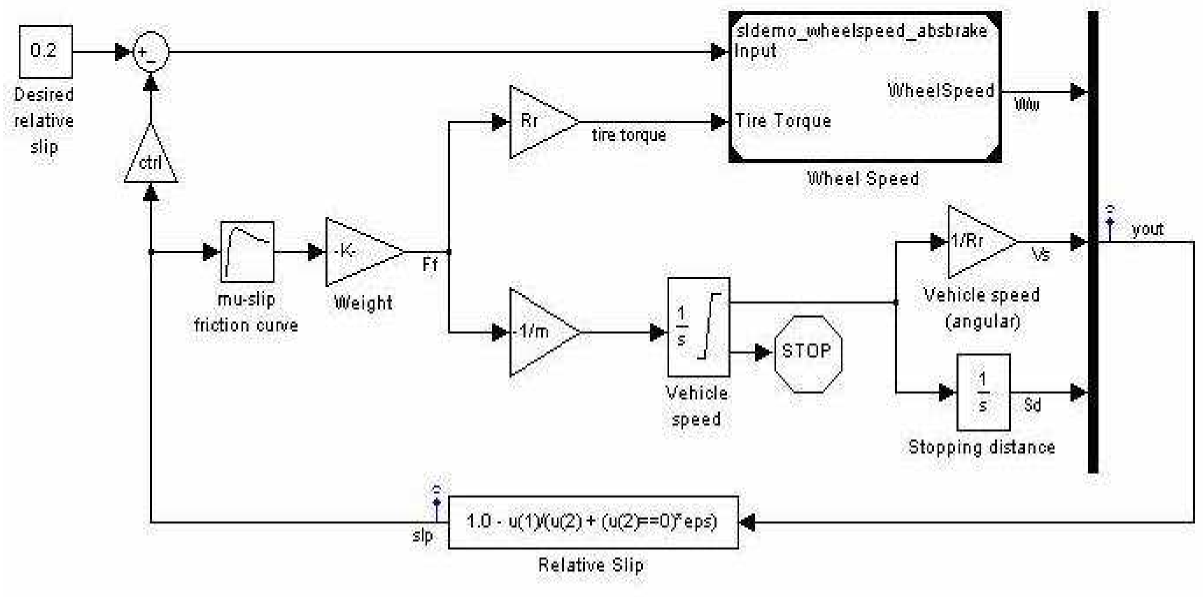

Figure 6.Simulink Model of the ABS

In the above figure, the wheel speed, vehicle speed and the stopping distance are measured and the error value is fed back through the feedback path. Also, tire torque and the relative slip are fed as inputs to the wheel speed block. Notice that the model is a reference model which has its own internal block. Double click on the 'Wheel Speed' subsystem in the model window to open it. Given the wheel slip, the desired wheel slip, and the tire torque, this subsystem calculates the wheel angular speed.

To control the rate of change of brake pressure, the model subtracts actual slip from the desired slip and feeds this signal into a bang-bang control (+1 or -1, depending on the sign of the error). This on/off rate passes through a first-order lag that represents the delay associated with the hydraulic lines of the brake system. The model then integrates the filtered rate to Fig yield the actual brake pressure. The resulting signal, multiplied by the piston area and radius with respect to the wheel (K_f), is the brake torque applied to the wheel.

The model multiplies the frictional force on the wheel by the wheel radius (R_r) to give the accelerating torque of the road surface on the wheel. The brake torque is subtracted to give the net torque on the wheel. Dividing the net torque by the wheel rotational inertia, I, yields the wheel acceleration, which is then integrated to provide wheel velocity. In order to keep the wheel speed and vehicle speed positive, limited integrators are used in this model.

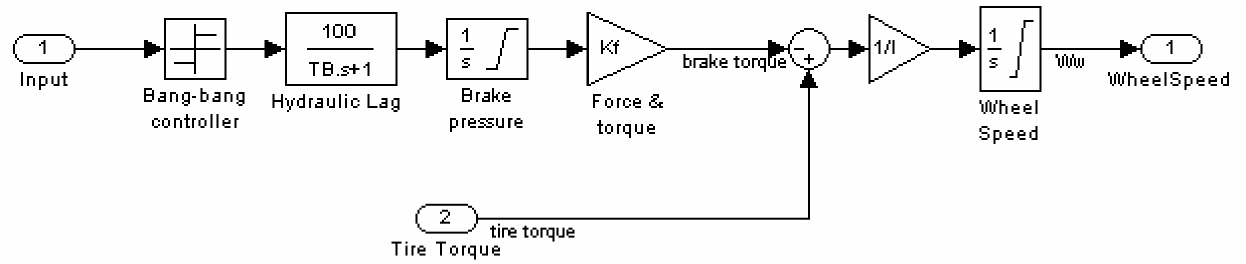

Figure 7.Wheel Speed Model for the ABS

After we build the ABS model in simulink, we have to configure the parameters related to simulation of the model. We need to specify that the signals are exported to the Matlab workspace where they are analyzed and results are viewed. This is done by checking the signal logging field in the **configuration parameters** option provided in the **simulation** tab.

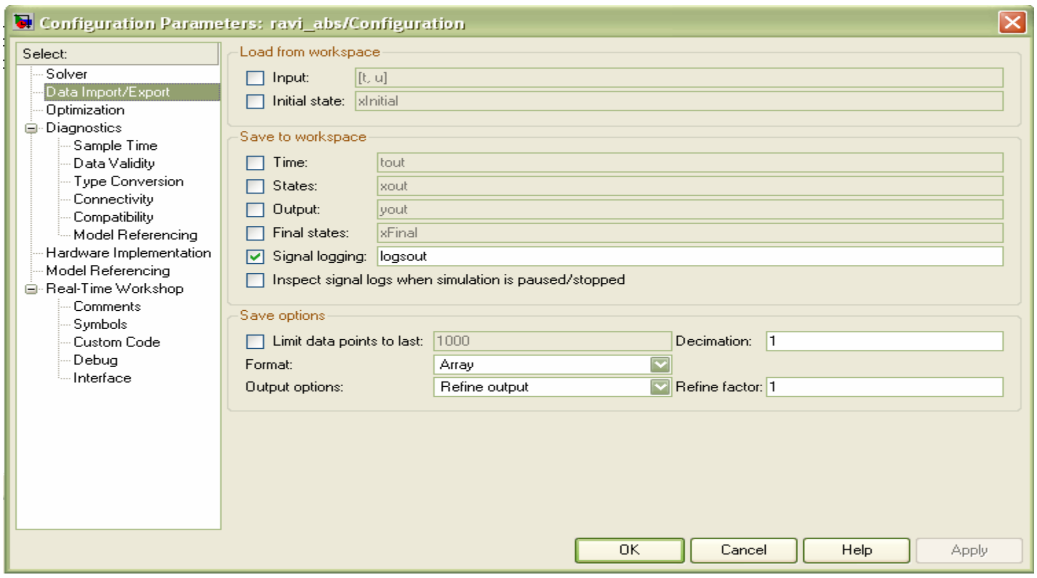

Figure 8.Configuring Parameters for the model

We make a Matlab code which makes use of the inputs and outputs used by the simulink model and we plot the waveforms.

ABS CODE

```
h = findobj(0, 'Name', 'ABS Speeds');
ifisempty(h),
h=figure('Position',[26 239 452 257],...
  'Name','ABSSpeeds',...
  'NumberTitle','off');
end
figure(h)
set(h,'DefaultAxesFontSize',8)
logsout.unpack('all');
plot(Vs.Time, Vs.Data);
set(findobj('type','line'),'color',[0 1 0]);
hold on;
plot(Ww.Time, Ww.Data);
title('Vehicle speed and wheel speed');
ylabel('Speed(rad/sec)');
xlabel('Time(secs)');
set(gca,'Position',[0.1300 0.1500 0.7750 0.750]);
set(get(gca,'xlabel'),'FontSize',10);
set(get(gca,'ylabel'),'FontSize',10);
set(get(gca,'title'),'FontSize',10);
 % Plot arrow with annotation
hold on
plot([5.958; 4.192],[36.92; 17.29],'r-',[5.758; 5.958; 6.029],[36.55; 36.92; 35.86],'r-' )
text (8.533,54.66, 'Vehicle speed (\omega_v)','FontSize',10)
plot([7.14; 8.35],[43.1; 56.3],'r-',[7.34; 7.14; 7.07],[43.4; 43.1; 44.1],'r-' )
text(4.342,15.69,'Wheel speed (\omega_w)','FontSize',10)
drawnow
hold off
h = findobj(0, 'Name', 'ABS Slip');
ifisempty(h),
h=figure('Position',[486 239 452 257],...
  'Name','ABSSlip',...
  'NumberTitle','off');
end
figure(h);
set(h,'DefaultAxesFontSize',8)
slp = logsout.slp.Data;
time = logsout.slp.Time;
plot(time,slp);
title('Slip')
xlabel('Time(secs)')
ylabel('Normalized Relative Slip')
set(gca,'Position',[0.1300 0.1500 0.7750 0.750])
set(get(gca,'xlabel'),'FontSize',10)
set(get(gca,'ylabel'),'FontSize',10)
set(get(gca,'title'),'FontSize',10)
```

RESULTS AND CONCLUSION

After building the model, we simulate it using the options provided in the same Simulink window.

RUNNING THE SIMULATION

WITH ABS

Press the "Play" button on the model toolbar to run the simulation. We can also run the simulation by executing the sim('FILE NAME') command in MATLAB. ABS is turned on during this simulation.

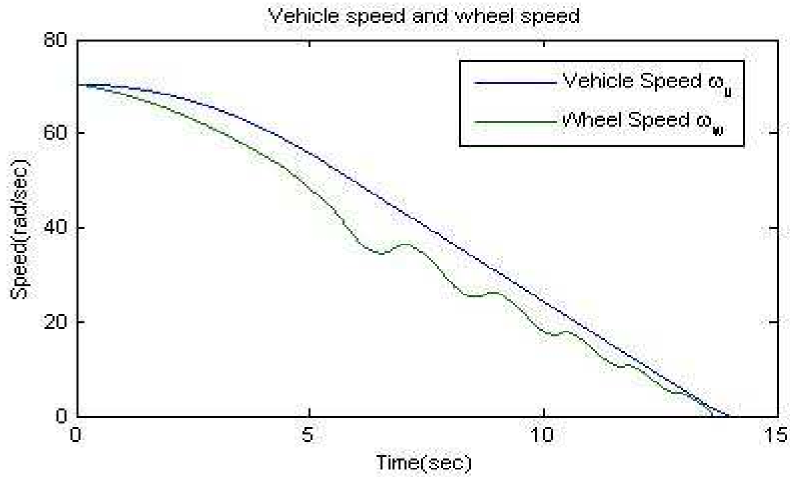

Figure 9.Vehicle Speed and Wheel Speed (with ABS)

The model logs relevant data to MATLAB workspace. Logged signals have a blue indicator. In this case **yout** and **slp** are logged (see the model).The above figure visualizes the ABS simulation results. The first plot in figure shows the wheel angular velocity and corresponding vehicle angular velocity. This plot shows that the wheel speed stays below vehicle speed without locking up, with vehicle speed going to zero in less than 15 seconds.

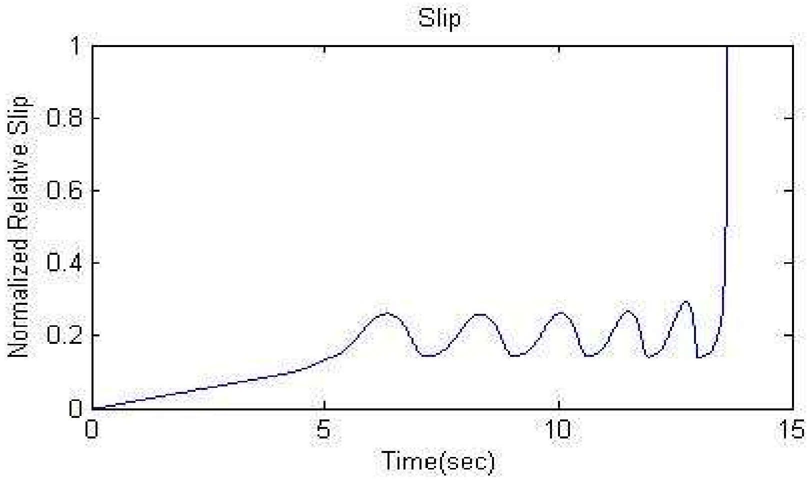

Figure 10.Normalised Relative Slip (with ABS)

WITHOUT ABS

For more meaningful results, consider the vehicle behavior without ABS. At the MATLAB command line, set the model variable ctrl = 0. This disconnects the slip feedback from the controller, resulting in maximum braking. The results are shown in the figure below.

ctrl = 0;

Now run the simulation again. This will model braking without ABS.

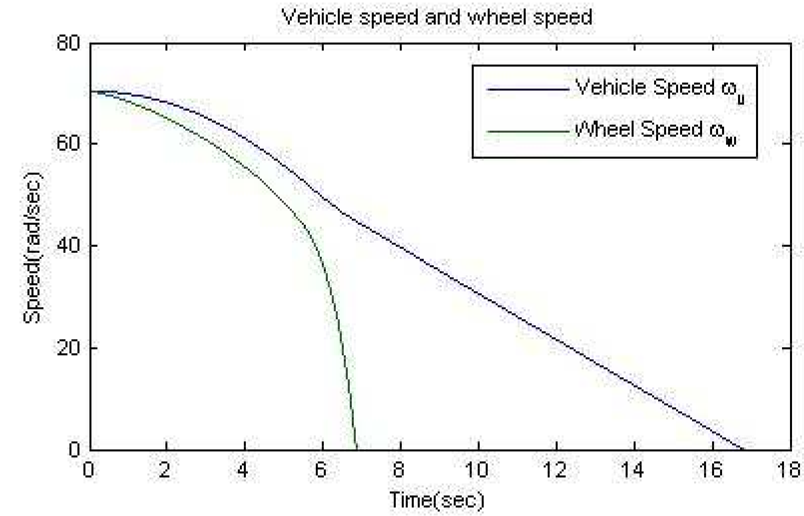

Figure 11.Vehicle Speed and Wheel Speed (without ABS)

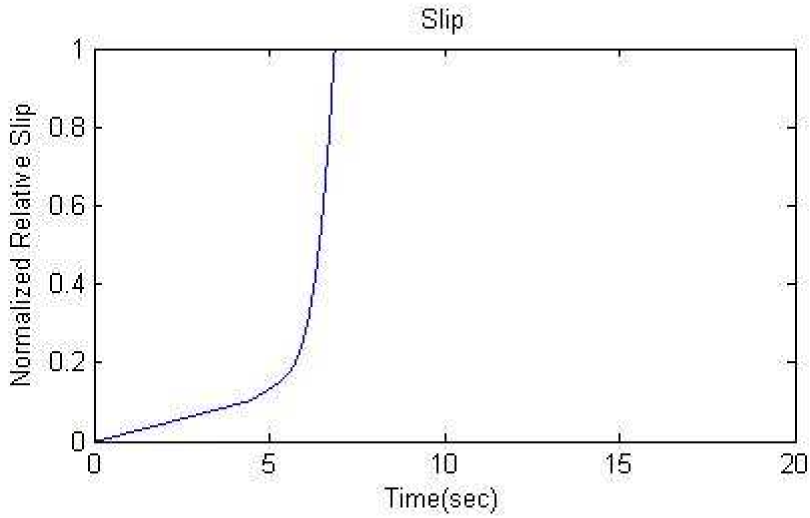

Figure 12.Normalized Relative Slip (without ABS)

The above shown results are observed when the slip is set at its peak value i.e. 0.2. Now, we also consider two more cases in which the slip values are 0.1 and 0.3 respectively.

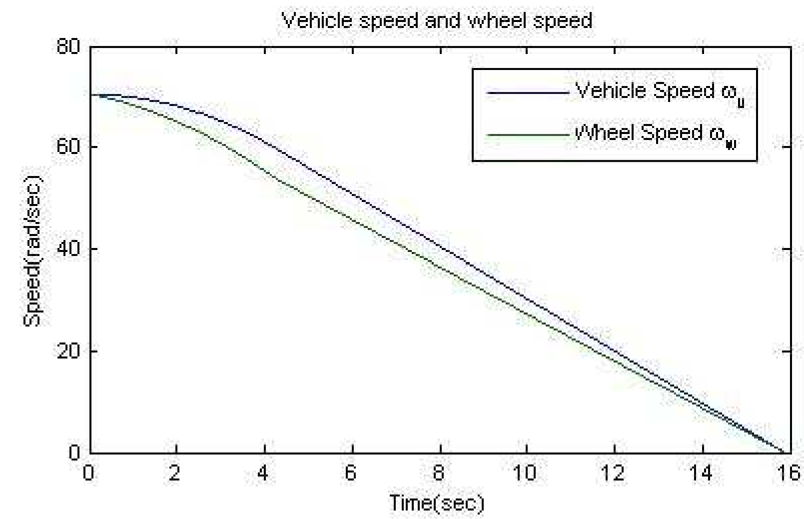

Figure 13.Vehicle Speed & Wheel Speed with ABS (slip=0.1)

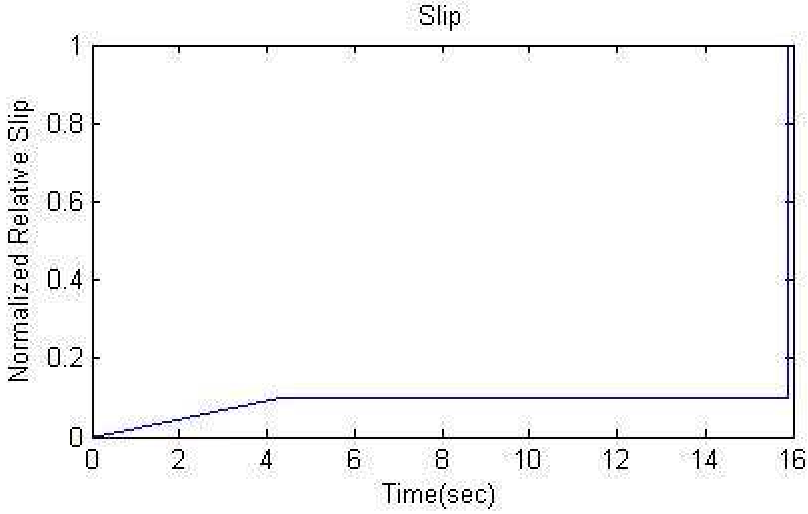

Figure 14.Normalized Relative Slip with ABS (slip=0.1)

Note that, when ctrl=0, i.e. when the ABS system is disabled, the results will be same as in fig 5.3 and fig 5.4.Now, we change the desired relative slip value to 0.3 and observe the results.

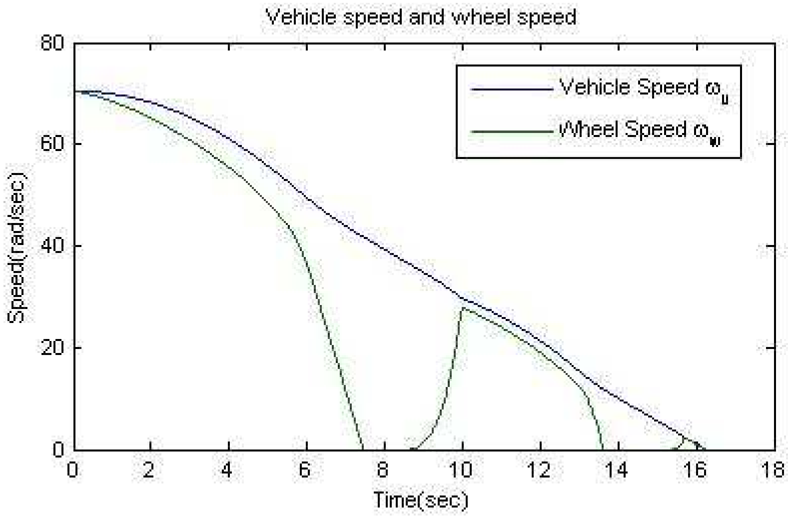

Figure 15.Vehicle Speed & Wheel Speed with ABS (slip=0.3)

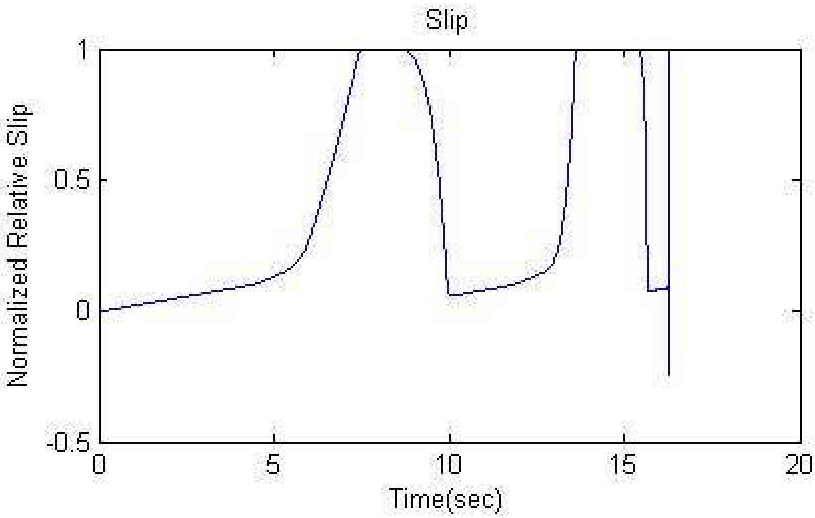

Figure 16.Normalized Relative Slip with ABS (slip=0.3)

BRAKING WITH ABS VS BRAKING WITHOUT ABS

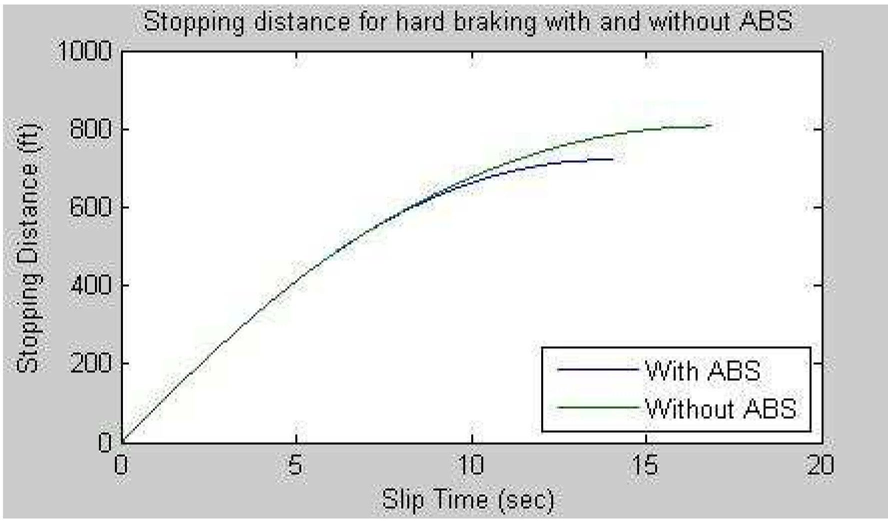

Figure 17.Stopping distance for hard braking with and without ABS

In the plots above its observe that the wheel locks up in about seven seconds. The braking, from that point on, is applied in a less-than-optimal part of the slip curve. That is, when slip = 1, as seen in the lower plot of fig 5.3, the tire is skidding so much on the pavement that the friction force has dropped off. This is, perhaps, more meaningful in terms of the comparison shown in Fig 5.9. The distance traveled by the vehicle is plotted for the two cases. Without ABS, the vehicle skids about an extra 100 feet, taking about three seconds longer to come to a stop.

CONCLUSIONS

This model demonstrates how we can use Simulink to simulate a braking system under the action of an ABS controller. We have also simulated the model and observed the results with using ABS and without using ABS. The controller in this example is idealized, but we can use any proposed control algorithm in its place to evaluate the system's performance. We can also use the Real-Time Workshop with Simulink as a valuable tool for rapid prototyping of the proposed algorithm. C code is generated and compiled for the controller hardware to test the concept in a vehicle. This significantly reduces the time needed to prove new ideas by enabling actual testing early in the development cycle.

REFERENCES

[1]. "Modeling and Control of an Intelligent Anti-Lock Braking System" by MOH. LUTFI WIJAYA, Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, Dec 2005.
[2]. Learning Programming Using MATLAB-Khalid Sayood.
[3]. Automotive Handbook, Robert Bosch.
[4]. Brian R. Hunt, Ronald L. Lipsman, Jonathan M. Rosenberg. A guide to MATLAB for Beginners and Experienced Users.
[5]. Introduction to Simulink with Engineering Applications by Steven T. Karris, Orchard Publications.

