Simulink Model of Anti-lock Braking System

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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 roads, 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 the wheel speed sensors, a hydraulic modulator, and an electronic control unit. The ABS has a feedback control system that modulates the brake pressure 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.

System Design:

A 4-wheeled vehicle is to decelerate from a speed of 44m/sec to standstill without wheel locking. The coefficient of friction between the tyres and the road is known. The desired wheel slip is 0.2. Observed vehicle speed and slip over time, and the stopping distance.

Equations used:

- Tyre Torque:

$$tyre\ torque\ =\ \mu\ *\ N\ *\ R$$

Where, μ(mu) = coefficient of friction

N = Normal Force per wheel = $m\ *\ g/\ 4$

m = mass of vehicle ; g = earth's gravity

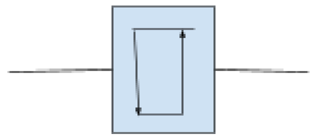
R = Radius of wheel

- Bang Bang Controller:

It is used to find the wheel speed.

Output of Bang Bang Controller is 1, if the input is greater than 0 and,

Output is -1, if the input is less than 0.



Bang Bang Controller is connected to a transfer function which represents the hydraulic lag once the brake is applied. The output is integrated over time to get the brake torque/ brake force.

- Difference between braking torque and tyre torque computes the deceleration of the vehicle. This difference is divided by moment of inertia (I) to give give acceleration ($a = torque / I$) or deceleration in this case. This gives wheel speed.

- $Equivalent\ vehicle\ angular\ acceleration = -\ (Tyre\ torque\ /\ (Vehicle\ mass\ *\ Wheel\ Radius))$

Where, negative sign is for deceleration.

- $Equivalent\ vehicle\ angular\ velocity = Integral\ of\ angular\ acceleration$

$$F = m * a$$

$$T = F * r = m * a * r$$

$$a = T/(m * r)$$

$$v = \int a\, dt$$

Using these formulae vehicle speed is calculated.

- $Actual\ relative\ slip = 1 - (Wheel\ speed\ /\ Vehicle\ speed)$

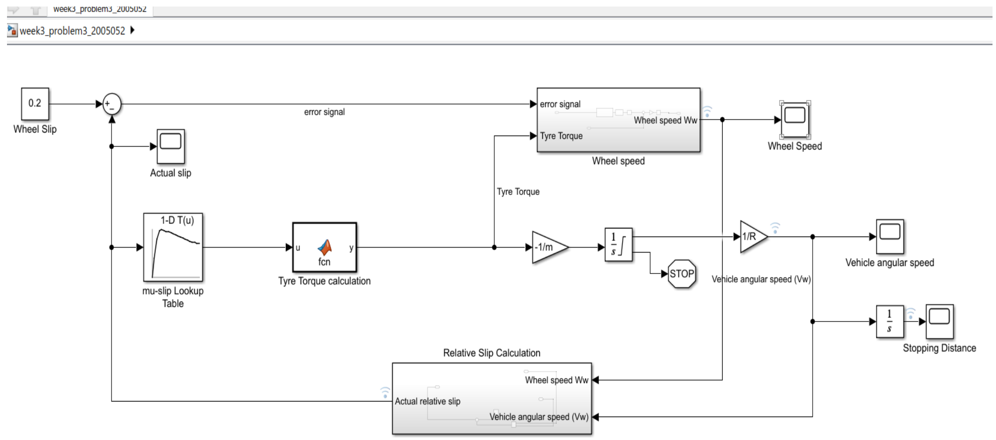


Figure 1: Model Designed in simulink

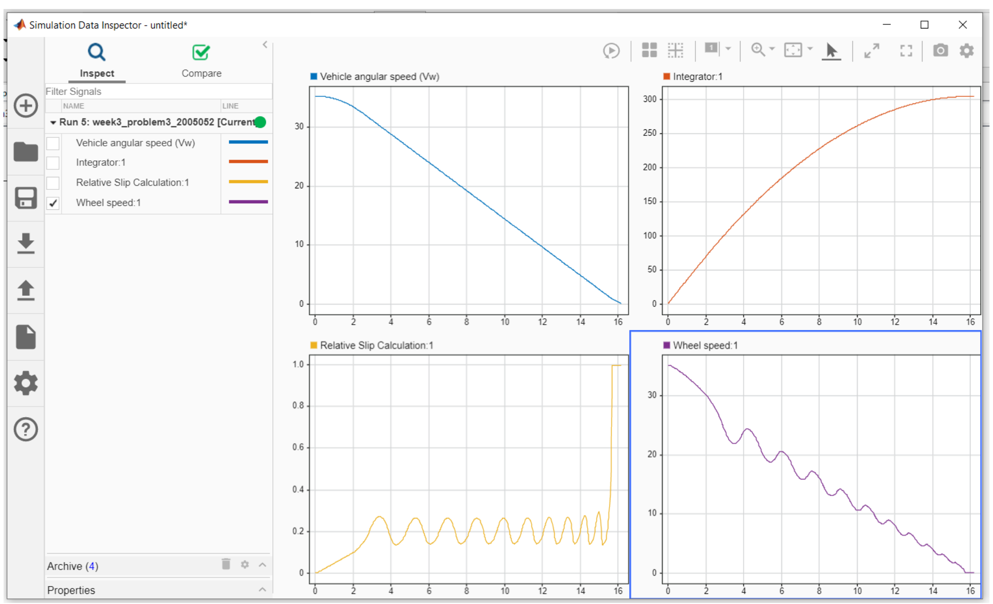


Figure 2: Outputs as seen in Data Inspector

The system parameters are as follows:

Parameter	**Symbol**	**Value**
Earth's gravity	g	9.8100 m/sec^2
Mass of the vehicle	m	75 kg
Radius of the wheel	R	1.2500 m
Initial Speed	v0	44 m/sec
Inertia	I	6 kg-m^2

Callbacks:

Callbacks are used in the subsystem to import the initial system parameters as variables in the model for its different operations.

Data Inspector:

Data Inspector is used to log actual relative slip, vehicle angular velocity, wheel speed and is used to observe the stopping distance.

The data inspector is particularly used to observe the system performance with respect to dips and rises and have a comparative study by altering the test conditions.

Solver Selection Strategy:

ODE-45 solver is used as the model does not have any high order ODEs and is non-stiff, also the system needed a variable step continuous solver. A fairly high enough accuracy was provided by using the ODE-45 solver in the simulations so it was chosen.

Look-up Table:

A one dimensional look-up table block was created to map the coefficient of friction (mu) to the value of slip.

MATLAB Function block

A custom MATLAB - Function block was created to calculate the tyre torque from the value of coefficient of friction received from the look-up table.