Problem statement:
Design complex automotive system of your choice.

Topic: <u>**Anti-Lock Braking System**</u>

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.
It simulates the dynamic behavior of a vehicle under hard braking conditions. The model represents a single wheel, which may be replicated a number of times to create a model for a multi-wheel vehicle.

The objectives of antilock systems are threefold:
1. To reduce stopping distances
2. To improve stability
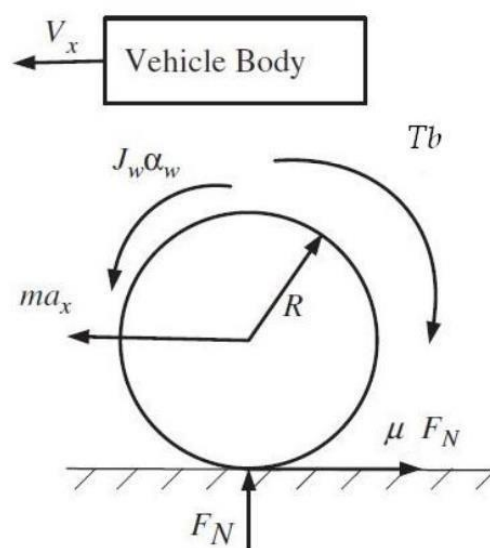3. To improve steerability during braking.

Mathematical Modelling:

Figure 1: Quarter Vehicle Model

The longitudinal velocity of the vehicle and the rotational speed of the wheel constitute the degrees of freedom for this model. The governing two equations for the motions of the vehicle model are as follows:
For braking force balance in longitudinal direction (vehicle)

$$m\,a_x = -\mu\,F_N \implies m\frac{d\,V_x}{d\,t} = -\mu\,F_N \tag{1}$$

Summing torque at wheel centre (wheel)

$$J_\omega\,\alpha_\omega = \mu\,R\,F_N - T_b \implies J_\omega\,\dot\omega = \mu\,R\,F_N - T_b \tag{2}$$

For convenience a slip ratio is defined according to:

$$\lambda = \frac{V_x - \omega\,R}{V_x} \tag{3}$$

Differentiating on both sides with respect to time (t), we get

$$\dot\lambda = \frac{\dot V_x\,(1-\lambda) - R\,\dot\omega}{V_x} \tag{4}$$

The nomenclature in above equations is presented as follows
V_x = linear velocity of vehicle
a_x = linear acceleration of vehicle
ω = rotational speed of wheel
α_ω = angular acceleration of wheel
T_b = braking torque
μ = friction coefficient
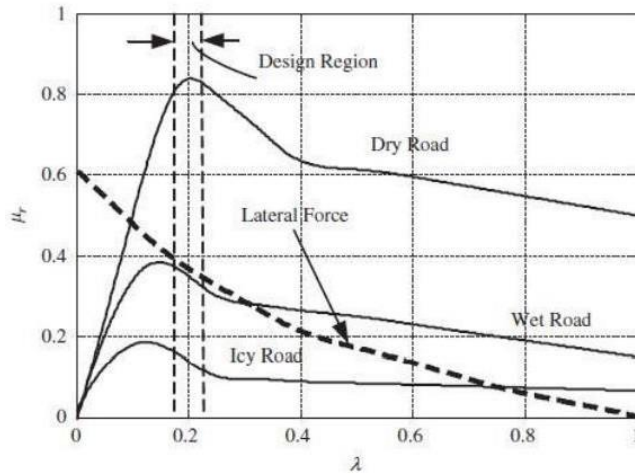R = radius of tire m = mass of the model

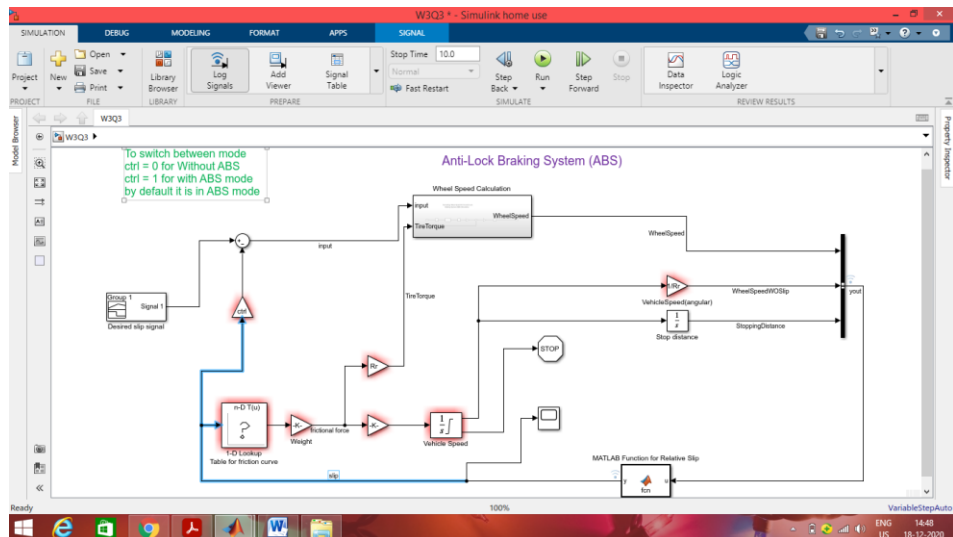**Figure 1: Frictional Coefficient of Road Surface v/s Wheel Slip Ratio**
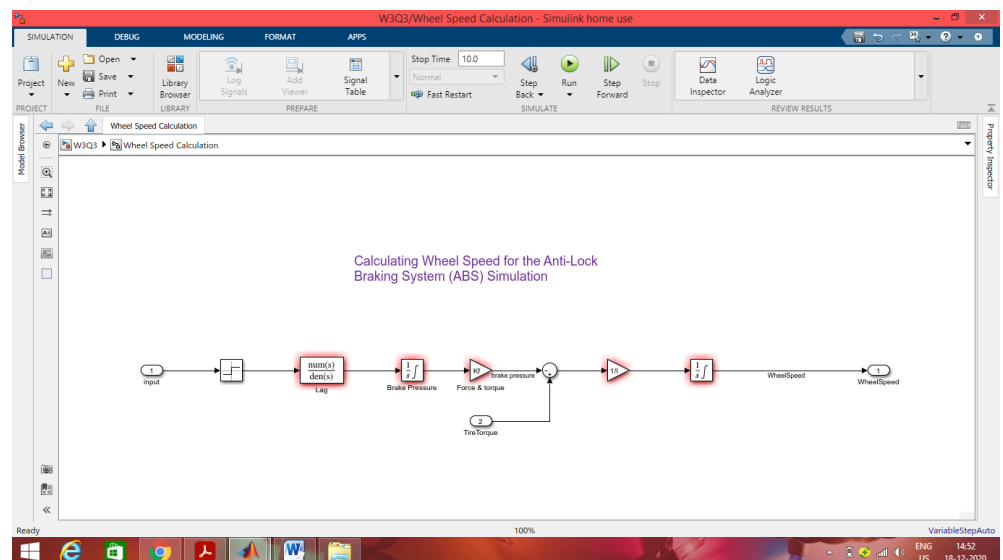
Figure 2: Simulink Model for ABS

Figure 3: Subsystem for calculating wheel speed

mu	slip
0	0
0.4	0.05
0.8	0.1
0.97	0.15
1.0	0.2
0.98	0.25
0.96	0.3
0.94	0.35
0.92	0.4
0.9	0.45
0.88	0.5
0.855	0.55
0.83	0.6
0.81	0.65
0.79	0.7
0.77	0.75
0.75	0.8
0.73	0.85
0.72	0.9
0.71	0.95
0.7	1.0

Table 1: Contents for lookup table

Modelled system in Simulink using equation 1, 2 and 3 and the look-up table content.

Input Values in InitFcn Callback:

```
%parameters
g = 32.18;
v0 =  88;
Rr = 15/12;
Kf = 1;
m = 50;
PressureBrakemax = 1500;
TB = 0.01;
I = 5;

slip = (0:0.05:1.0);
mu = [0 0.4 0.8 0.97 1.0 0.98 0.96 0.94 0.92 0.9 0.88 0.855 0.83
0.81 0.79 0.77 0.75 0.73 0.72 0.71 0.7];
ctrl = 0;
```

Solver Selection Setting:

By default using ode45 and stop field as 40 sec.

Output observed in Data Inspector:

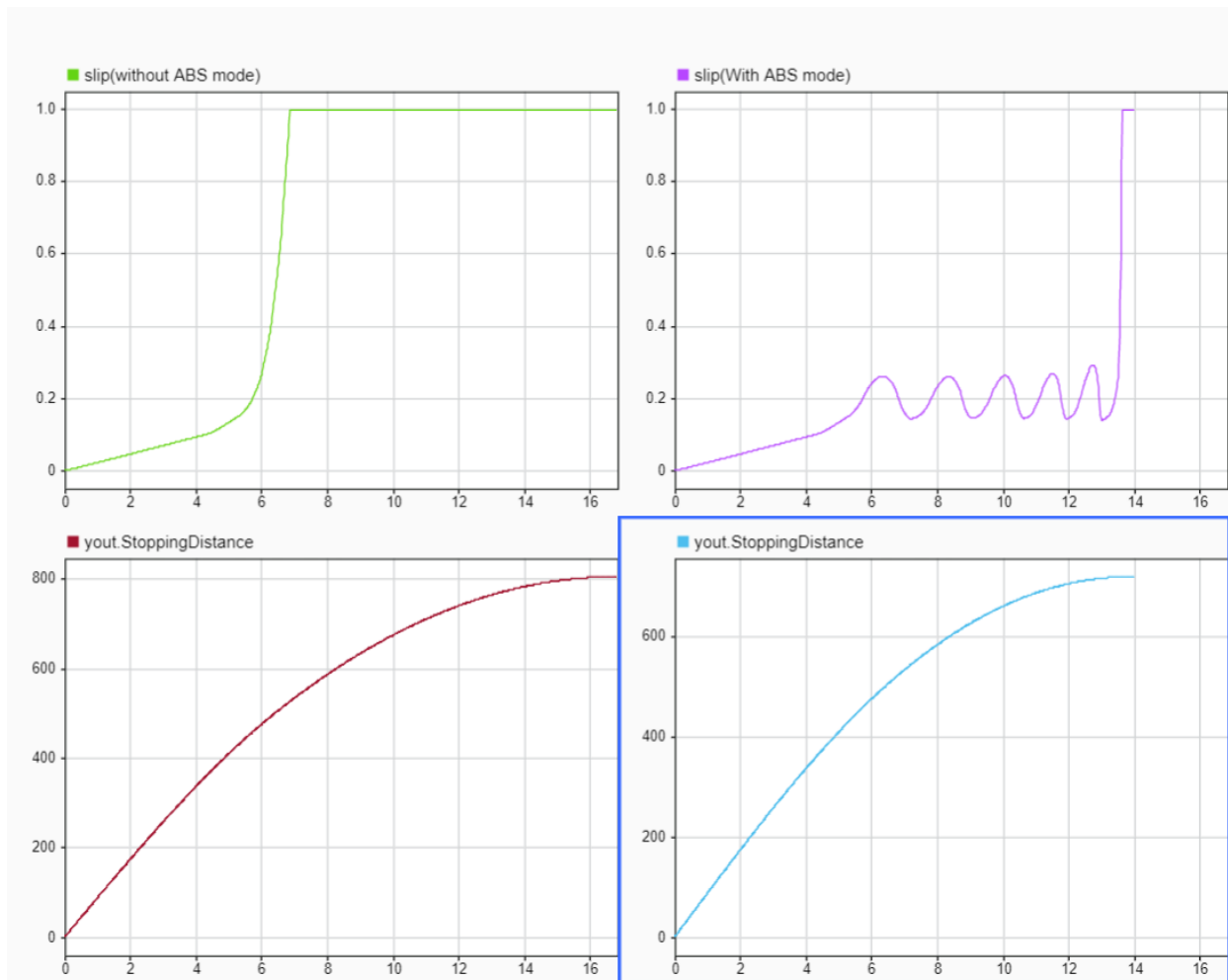For   ctrl = 0→Without ABS

      Ctrl = 1→with ABS

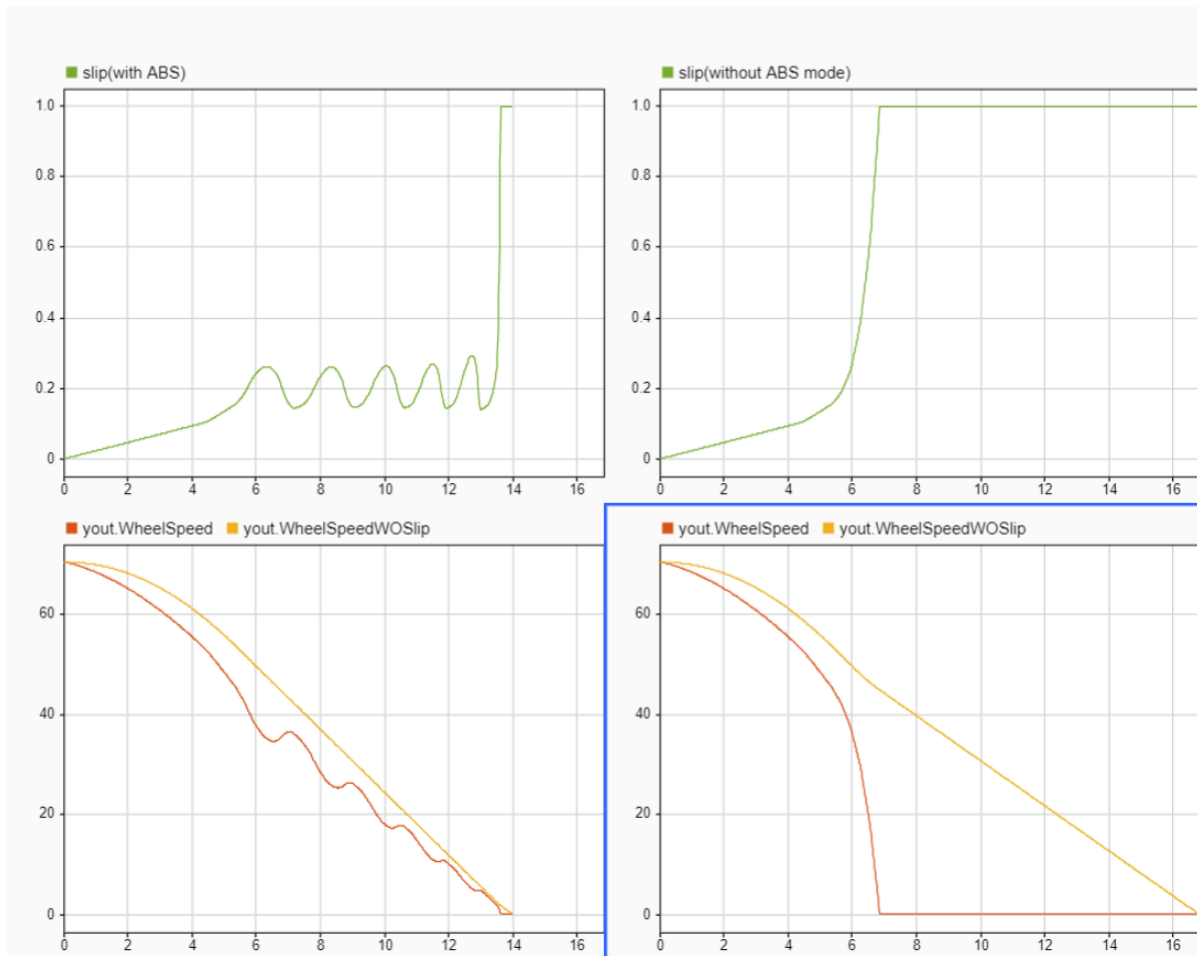**Figure 4: With and without ABS slip and Stopping distance**

Figure 5: Wheel and Vehicle speed for with and without ABS

Conclusion:
Anti-Lock braking system modelled and response of the system with and without ABS observed. It is seen that with ABS the stopping distance is reduced and stability and steer ability improved during braking.

Github link: https://github.com/saheli1998/MBD-W3-Q3.git

Reference:
https://in.mathworks.com/help/simulink/slref/modeling-an-anti-lock-braking-system.html