One Wheel Slip Control

Background

About Wheel Slippage

What is Wheel Slippage

Longitudinal Slip Percentage of a wheel, s - a measure of the amount of sliding at the road tire interface

slip is defined as following:

When Braking -1<s<0 : wheel lockup s=(w Re - Vx)/Vx

During Traction Loss 0<s<1 : wheel rotates without translational motion s=(w Re - Vx)/(w Re)

Why Control Wheel Slip

Wheel slip has a direct relationship with longitudinal and lateral tire forces. These reaction forces are what give control to the driver of a vehicle and are thus important.

The relationship can be described nonlinnearly and approximated with the following models: Magic Tire Formula Model (BNP), Nicolas-Comstock, and Modified Nicolas Comstock (MNC). These relationships and models can be explored further in the following live script: 'TireForceModeling.mlx'

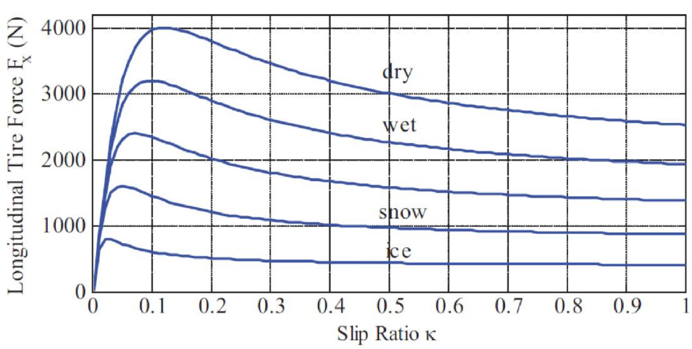

Fig. 1. General tire characteristics for longitudinal force versus tire slip ratio.

Note that the coefficient of friction of the road surface is also very important.

Anti-Lock Breaking System (ABS)

Antilock Breaking is a form of wheel slippage control for **breaking** and has three main benefits.

1. Decreased Stopping distance during full break

2. Maintain steering control while full breaking

3. Avoid rotational instability - spinouts when road conditions vary between car sides

These are summarised well in the following video: https://youtu.be/98DXe3uKwfc

Traction Control System (TCS)

Traction Control is a form of wheel slippage control for **gaining traction during driving in response to excess throttle** and has these benefits. TCS only applies to drive wheels.

1. Reduce unnecessary tire wear

2. Improve accelleration

3. Increased vehcile control

These benefits are achived through the following means.

Low speed: spinning wheel is breaked, this sends more power to the other wheels

Higher speed: engine output is throttled until all wheels regain grip: Throttle Injection or Ignition Angle

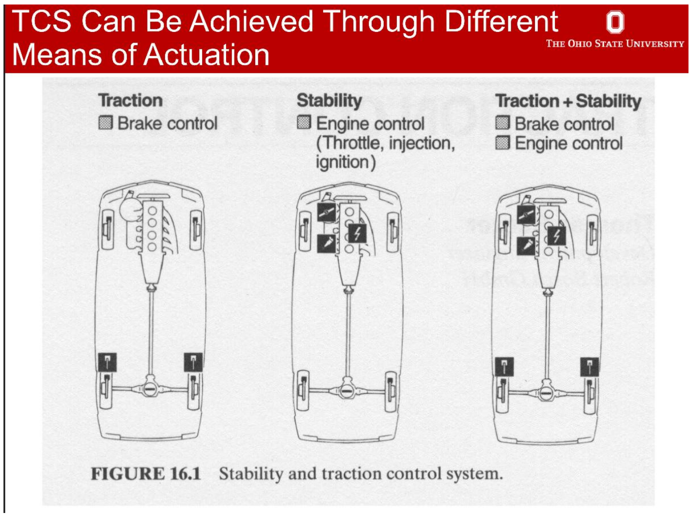

FIGURE 16.1 Stability and traction control system.

Demonstration of Single Wheel Slip Control for Longitudinal Dynamics

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Substitute existing model pieces found online and from professor Guvenc

- Magic Tire Formula (Part 1)
- Replace the Bang Bang Controller with a PID or other controller + Explain the rationale and design steps (Part 2)
- Do a Simulation Study for the ABS portion (Part 3) and then Modify the friction coefficient vs slip curve to imitate wet or icy roads. Comments
- Replace the TCS controller, same steps as part 2 (Part 4)
- Simualtion study for TCS same as part 3 (Part 5)
- Use the alternative implementation for desired wheel speed setpoint computation based on desired slip ratio and run the TCS

Part 0

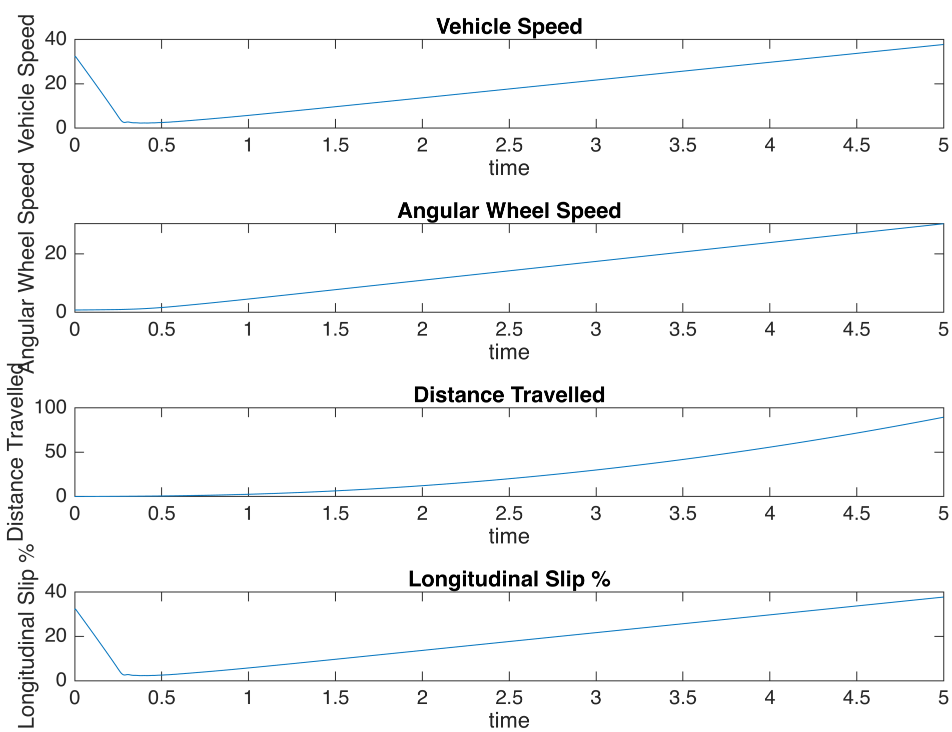
Unaltered Models for ABS and TCS

TCS First

```
addpath("UnalteredModels/")
disp('Unchanged TCS Model Outputs')
```

```
Unchanged TCS Model Outputs
```

```
load('OneWheelTCS.mat')
%outputs variables are the following:
%w  %linear wheel speed
% Vw %wheel velocity angular
% yout %distance travelled?
% slp %slip!
% t time
sim('OneWheelTCS.slx')
%Why is yout 3 in width?
ynames=["Vehicle Speed","Angular Wheel Speed","Distance Travelled","Longitudinal Slip
P = [yout w Vw slp]; %plots
for i = 1:1:4
    %figure(i)
    subplot(4,1,i)
    plot(t,P(:,i))
    xlabel('time')
    ylabel(ynames(i))
    title(ynames(i))
end
```



```
disp('end of TCS model outputs')
```

```
end of TCS model outputs
```

ABS Next

```
disp('Unchanged ABS Model Outputs')
```

```
Unchanged ABS Model Outputs
```

```
load('OneWheelABS.mat')
%outputs
sim('OneWheelABS.slx')
%outputs variables are the following:
% yout
   % Ww Vehicle Speed
   % Vs angular wheel speed
   % Sd Stopping Distance
ynames=["Vehicle Speed","Angular Wheel Speed","Stopping Distance","Slip %"];
P = [yout slp]; %plots
for i = 1:1:4
    %figure(i)
    subplot(4,1,i)
    plot(t,P(:,i))
    xlabel('time')
    ylabel(ynames(i))
    title(ynames(i))
end
disp('end of ABS model outputs')
```

```
end of ABS model outputs
```

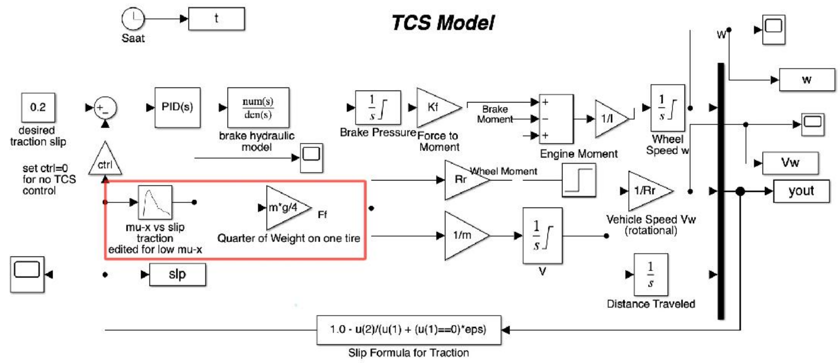
Part 1

Implement the magic tire formula in ABS and TCS models

replacing this area of the block diagram will eliminate the usage of the mu slip curve/table and calculate longitudinal force direclty through the magic tire formula

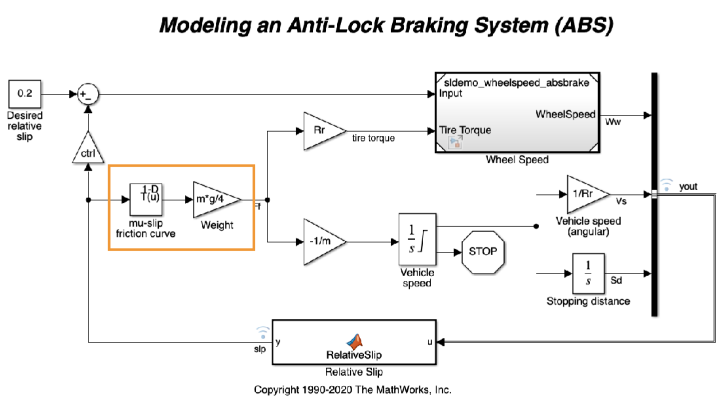
The area to be replaced in both diagrams:

TCS



this area takes s as an input, gives mu, the friction coefficient, and then multiplies by m*g/4 which is the normal force on one tire. therefore emulating mu*N = friction.

ABS



TCS First Again

```
clc; clear; close all;
rmpath("UnalteredModels/"),addpath("AlteredModels1/")
disp('Magic Tire Formula TCS Model Outputs')
```

```
Magic Tire Formula TCS Model Outputs
```

```
load('OneWheelTCS.mat'),sim("OneWheelTCSMT.slx")
ynames=["Vehicle Speed","Angular Wheel Speed","Distance Travelled","Longitudinal Slip
P = [yout w Vw slp]; %plots
for i = 1:1:4
    subplot(4,1,i)
    plot(t,P(:,i))
    xlabel('time'),ylabel(ynames(i)),title(ynames(i))
end
disp('end of TCS model outputs with Magic Tire Formula')
```

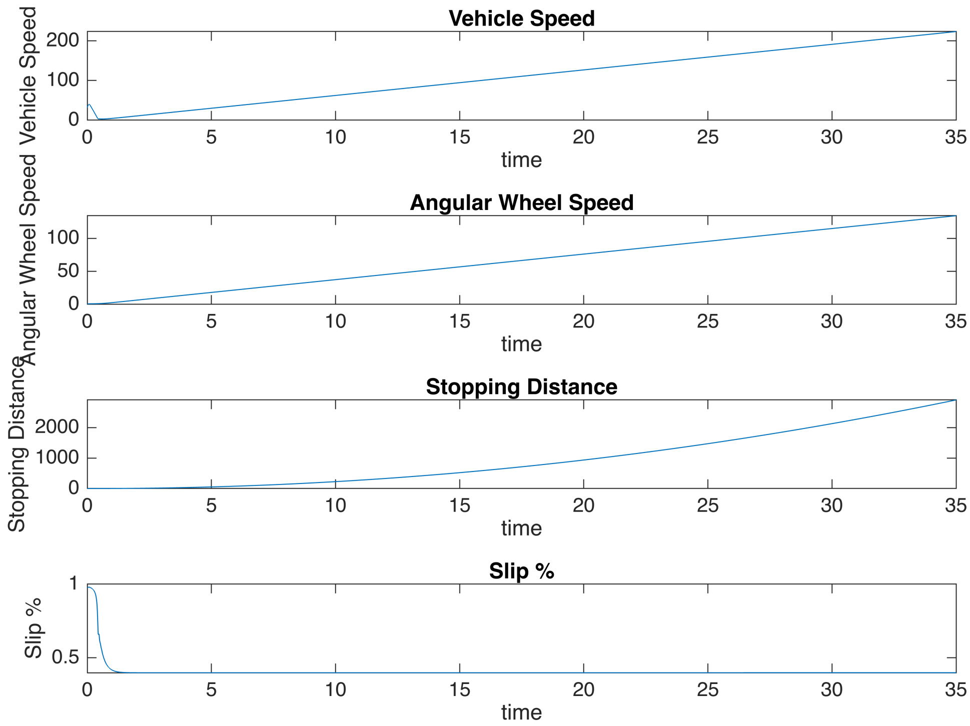
```
end of TCS model outputs with Magic Tire Formula
```

ABS Next

```
disp('Magic Tire Formula ABS Model Outputs'),load('OneWheelABS.mat')
```

Magic Tire Formula ABS Model Outputs

```
sim('OneWheelABSMT.slx')
ynames=["Vehicle Speed","Angular Wheel Speed","Stopping Distance","Slip %"];
P = [yout slp]; %plots
for i = 1:1:4
    subplot(4,1,i),plot(t,P(:,i)),xlabel('time'),ylabel(ynames(i)),title(ynames(i))
end
```




```
disp('end of ABS model outputs')
```

```
end of ABS model outputs
```