Term Project in Vehicle Dynamic Course

Dynamic Stability Analysis of a Omni Directional Vehicle

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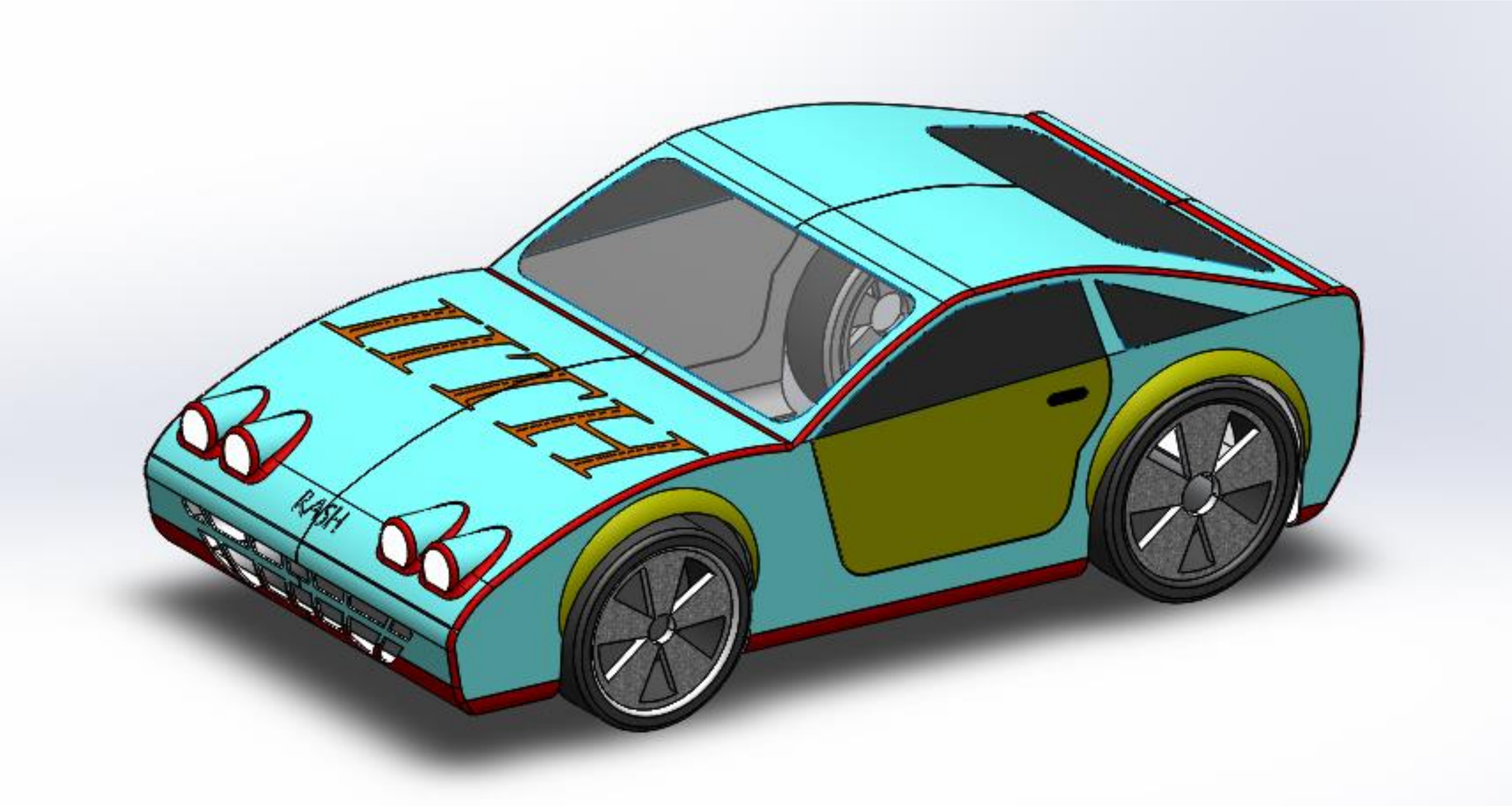
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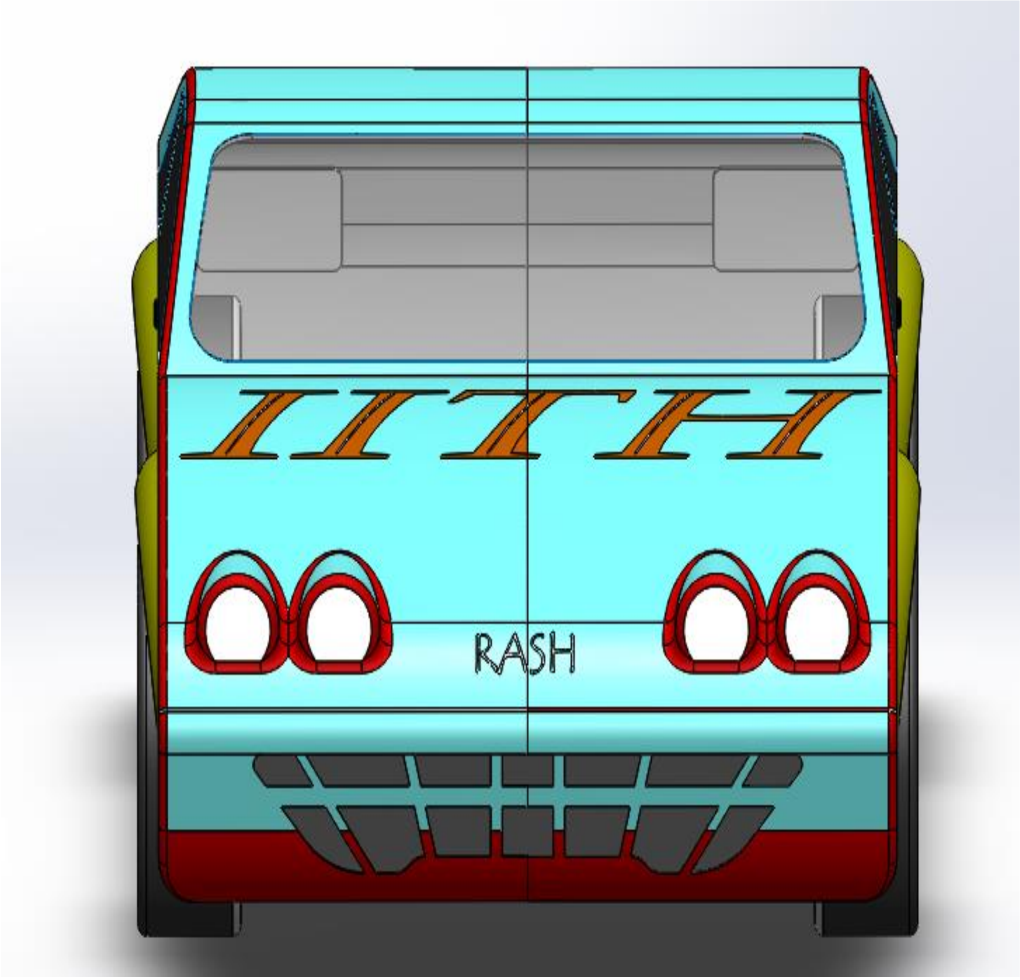
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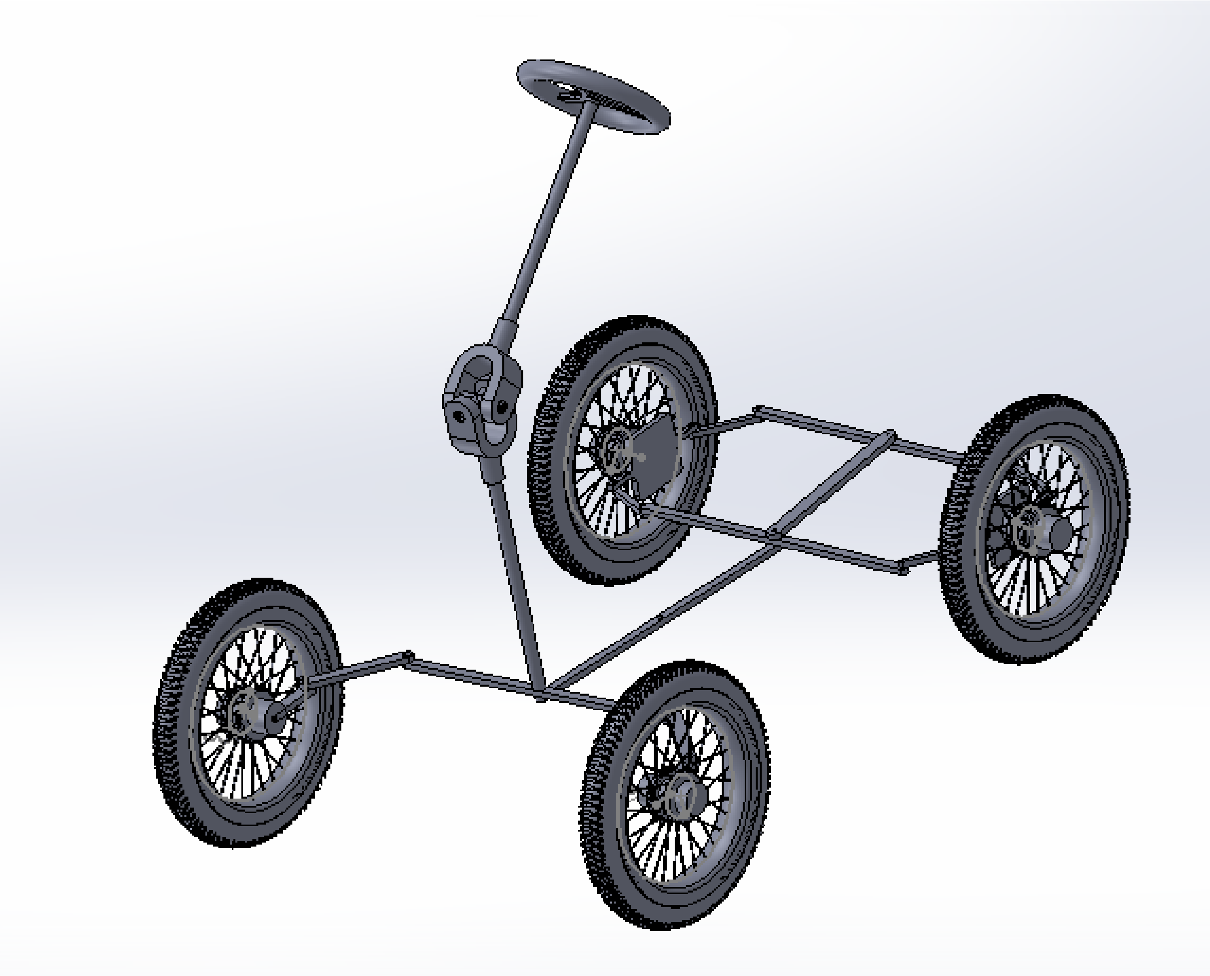


Omni-Directional Steering system

In a conventional vehicle ,steering angle is constrained by mechanical linkages between each vehicle i.e , +35 to -35 degrees. However , an omni-directional vehicle which has an independent steering system for each wheel , it has large steering angle constraint , from +90 to -90 degrees. This is model was developed from the area of robotics. In the area of advanced robotics, the wheel can be rotated by more than 90 degrees.

The steering angle of each wheel is given by

$$\delta_i = \operatorname{atan} 2(D^T(x_i - x_{ICR}), -D^T(y_i - y_{ICR}))$$

Where x_i, y_i are coordinates of wheels and x_{ICR}, y_{ICR} are coordinates of instantaneous center.

Tire Model

- Dugoff tire model is used to analyze the stability of vehicle.

$$F_y = C_\alpha \, tan\alpha f(\lambda)$$

$f(\lambda)= \lambda(2- \lambda)$ if $\lambda<1$

$= 1$ if $\lambda>1$

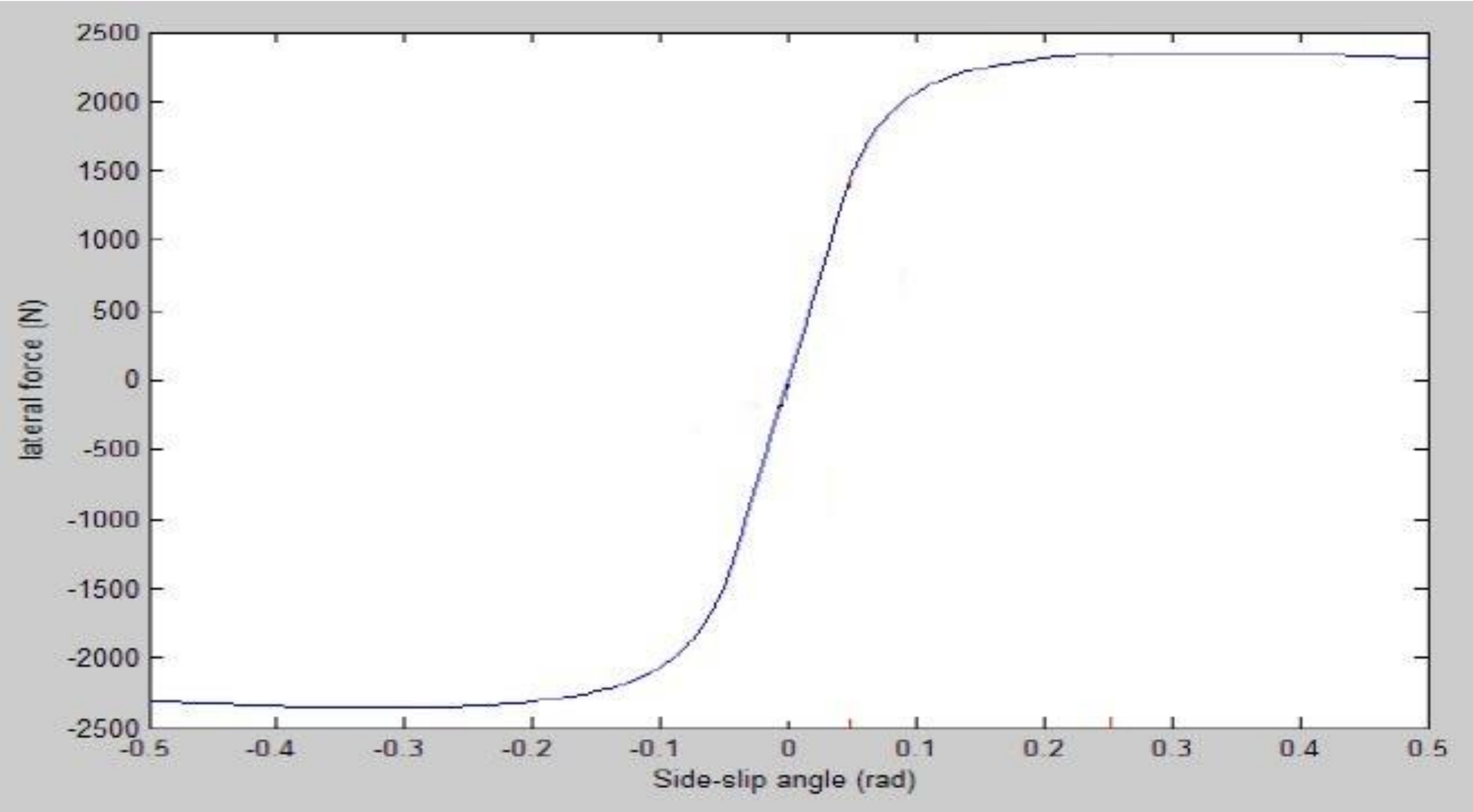
Where

$$\lambda = \frac{\mu F_z - \varepsilon_r v|tan\alpha|}{2|C_\alpha \, tan\alpha|}$$

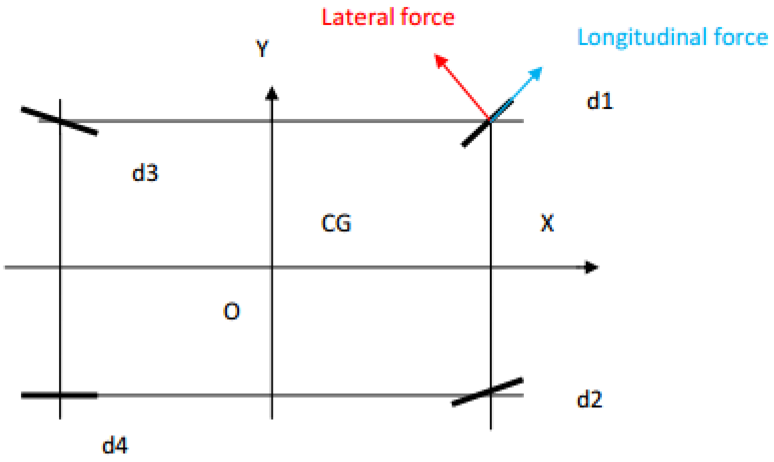
If $\lambda<1$, then $f(\lambda)= \lambda(2- \lambda)$, $F_y = C_\alpha \, tan\alpha f(\lambda)$ implies the tire is in non linear region.

If $\lambda>1$, then $f(\lambda)=1$, $F_y = C_\alpha \, tan\alpha$ implies the tire lies in linear region.

Lateral Force vs Sideslip angle



Vehicle Body Model



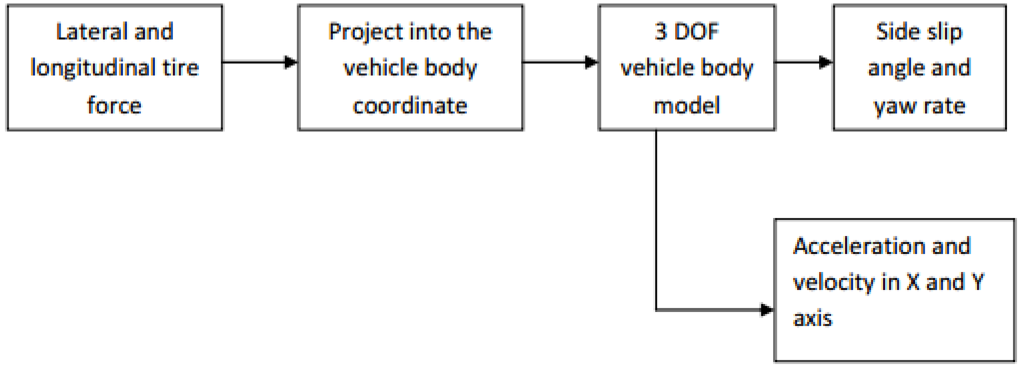
The inputs from the vehicle body dynamic model are the four lateral and longitudinal forces of tires calculated from the tire model. Since the steering angle of each wheel is different .

The equations of motion are

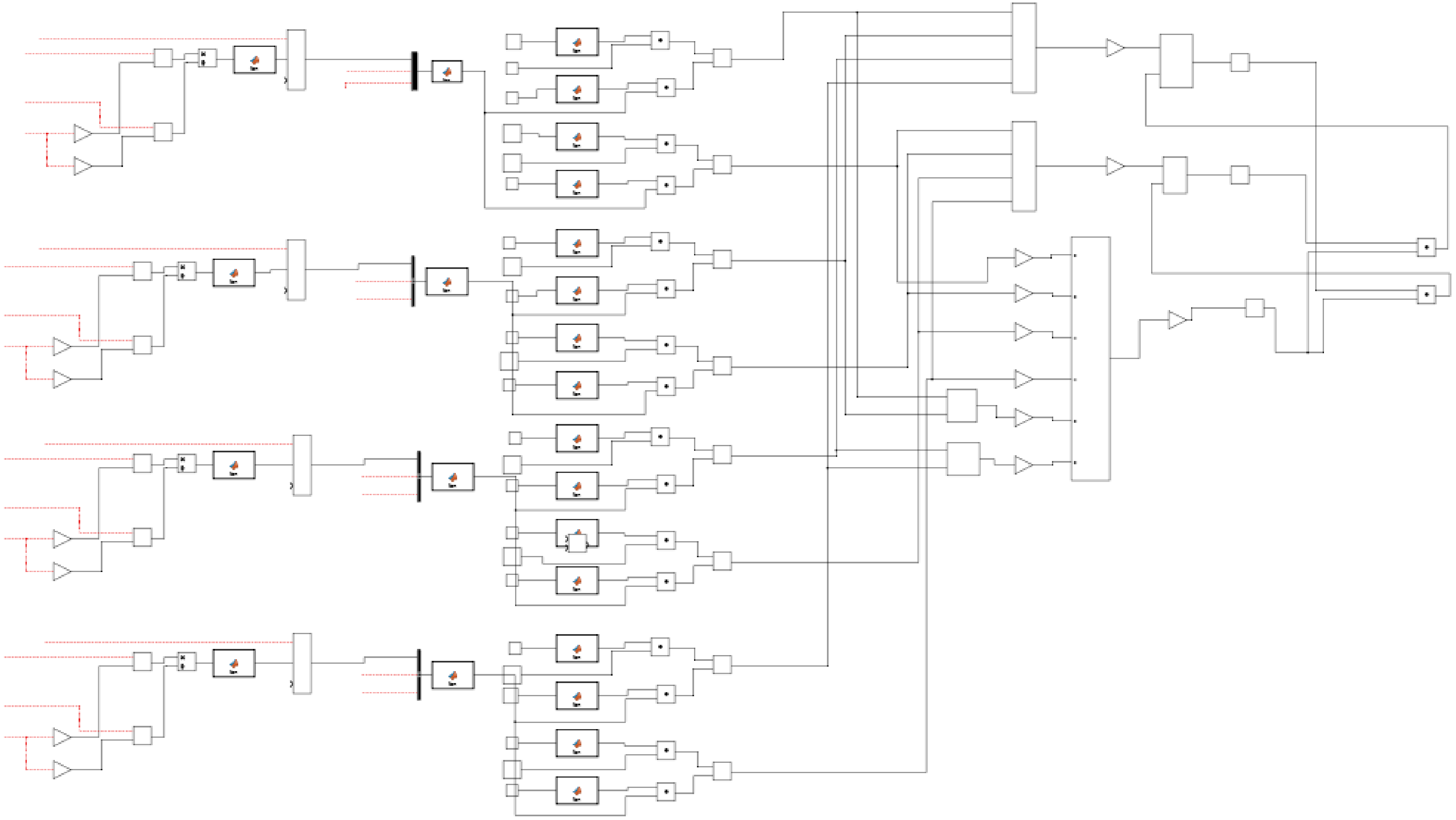
$$m(\dot{u} - u * r) = F_{xfl} + F_{xfr} + F_{xrl} + F_{xrr}$$

$$m(\dot{v} + v * r) = F_{yfl} + F_{yfr} + F_{yrl} + F_{yrr}$$

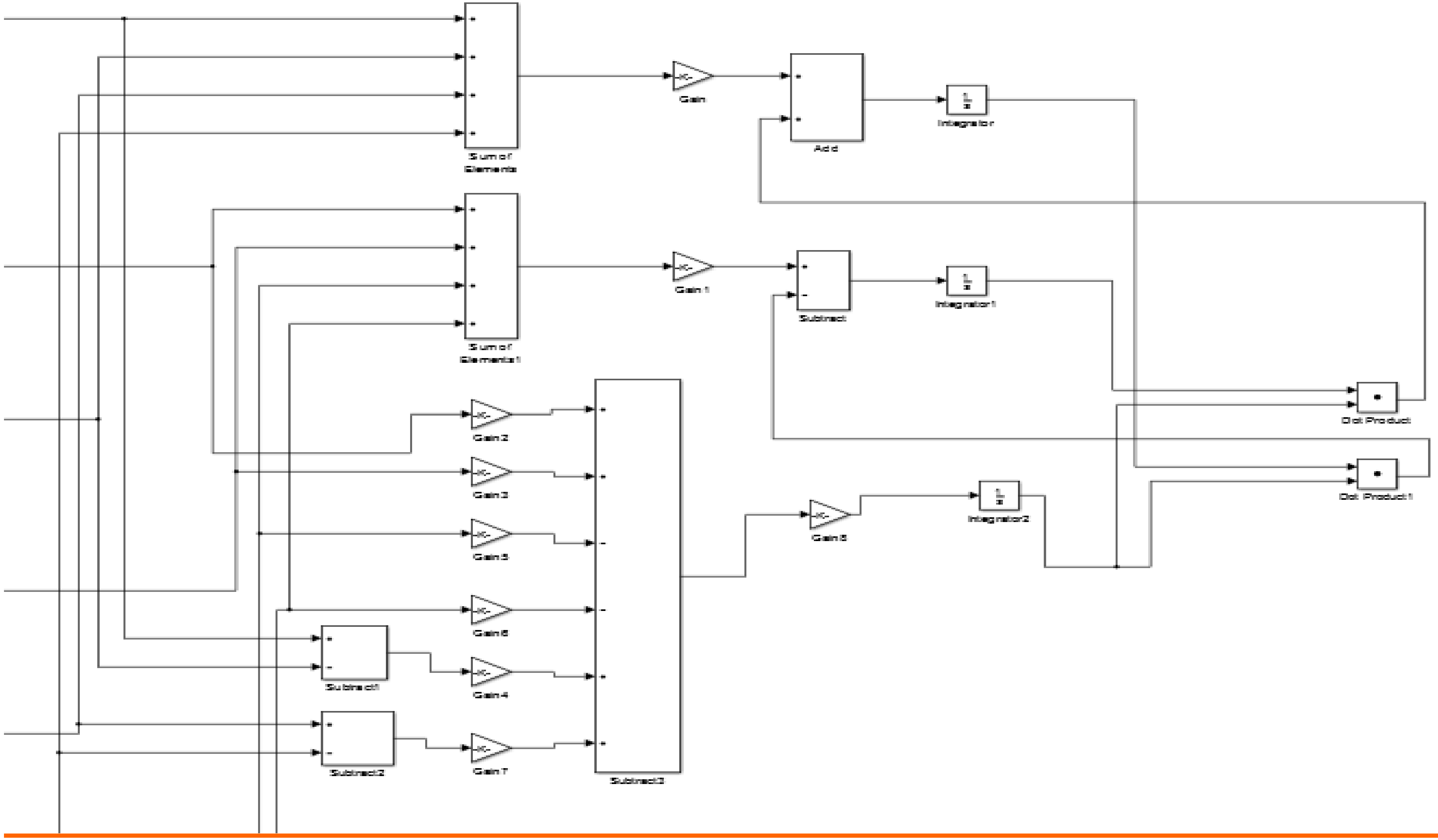
$$I\dot{r} = l_f\left(F_{yfl} + F_{yfr}\right) - l_r\left(F_{yrl} + F_{yrr}\right) + 0.5T_f\left(F_{yfl} - F_{yfr}\right) + 0.5T_r\left(F_{yrl} - F_{yrr}\right)$$



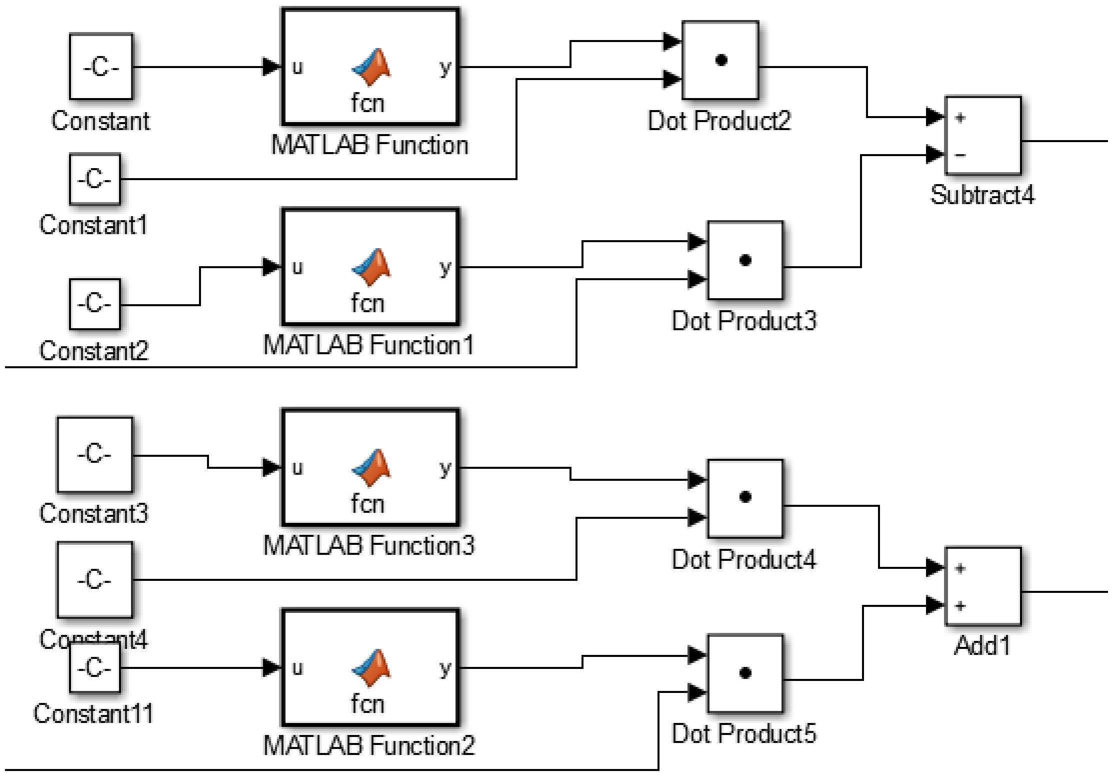
Entire Simulink model:



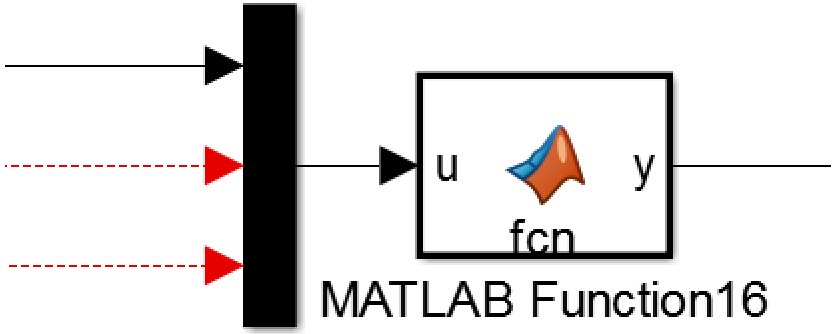
Model of vehicle yaw plane dynamics



Transfer model of governing equations:



Model of tire lateral force in 3DOF Yaw plane model using Dugoff model



Slip angle calculations:

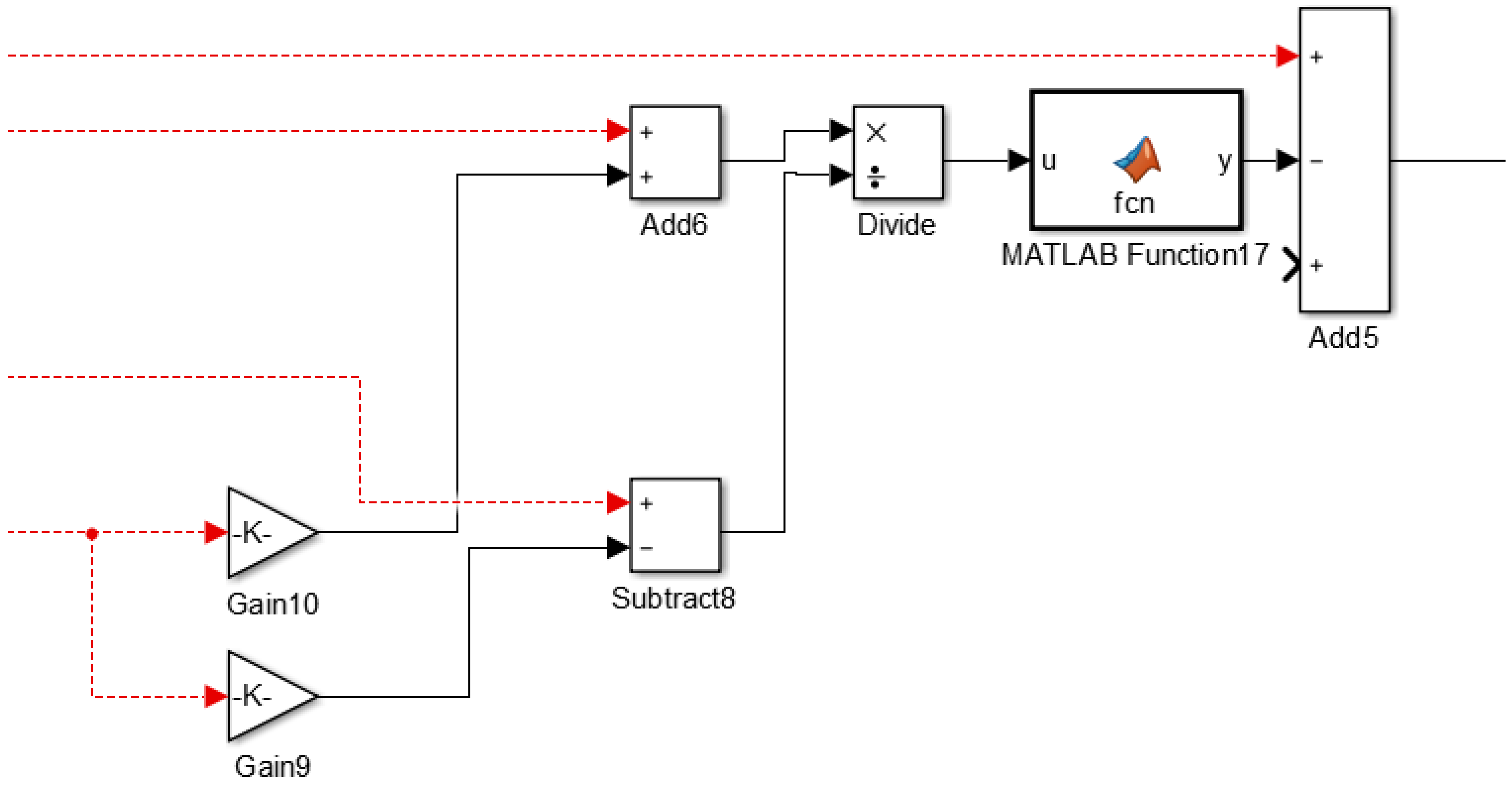
$$\alpha_{fl} = \delta_{fl} - \arctan\left(\frac{u + l_f r}{v - 0.5T_f r}\right)$$

$$\alpha_{fr} = \delta_{fr} - \arctan\left(\frac{u + l_f r}{v + 0.5T_f r}\right)$$

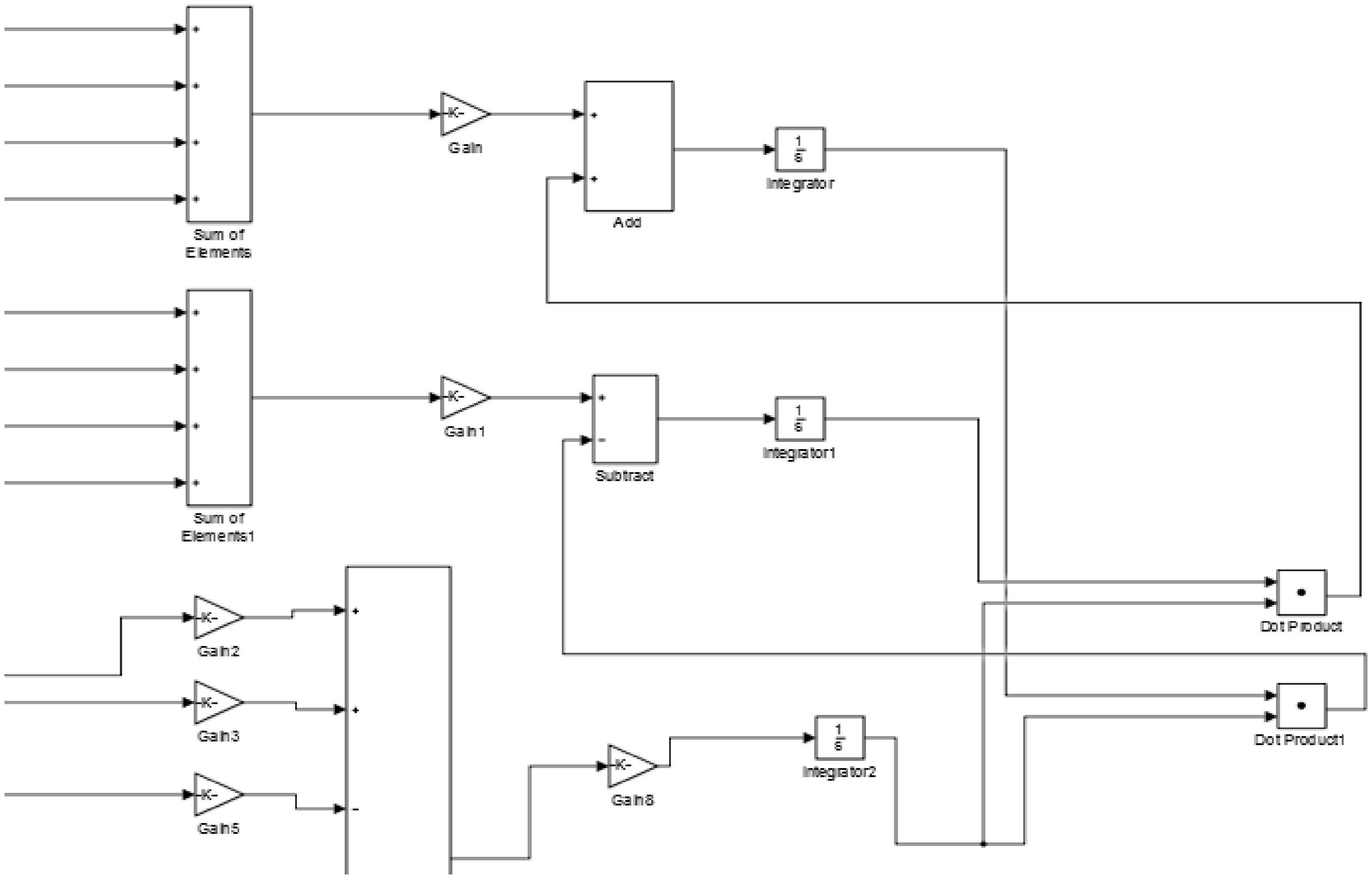
$$\alpha_{rl} = \delta_{rl} - \arctan\left(\frac{l_r r - u}{v - 0.5T_r r}\right)$$

$$\alpha_{rr} = \delta_{rr} + \arctan\left(\frac{l_r r - u}{v + 0.5T_r r}\right)$$

Model of side slip angle of a wheel:

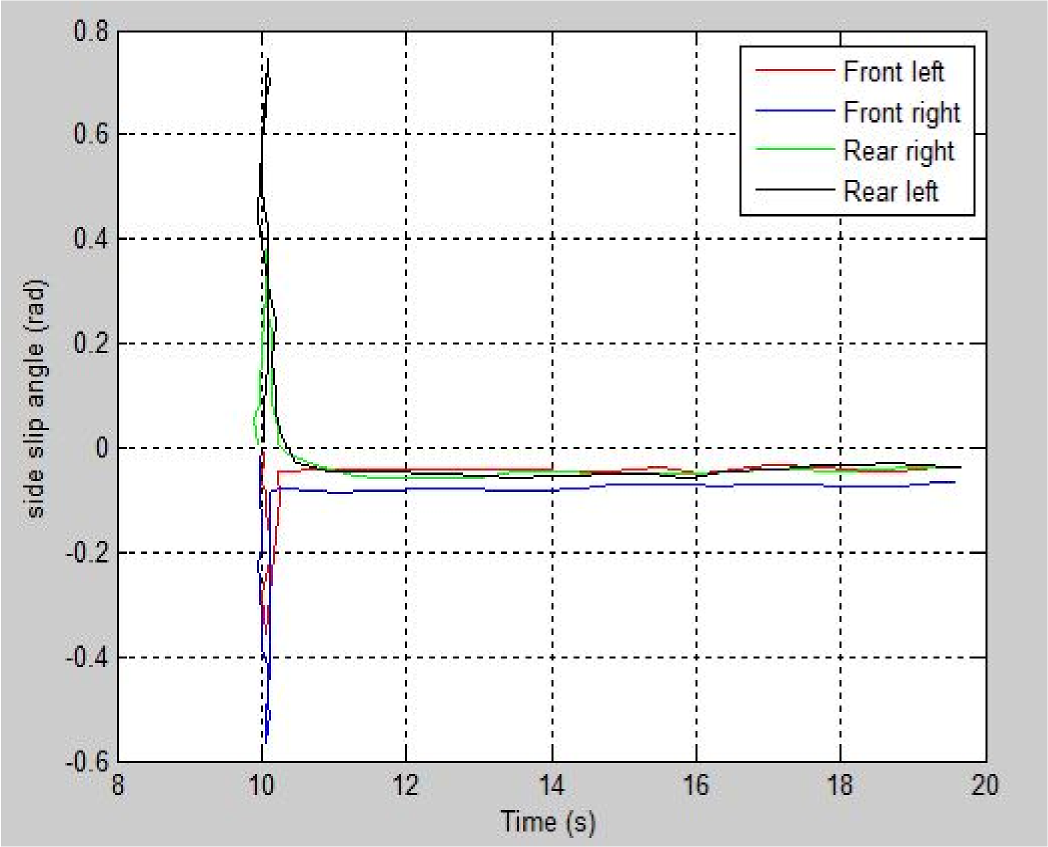


Part model to calculate velocities and yaw



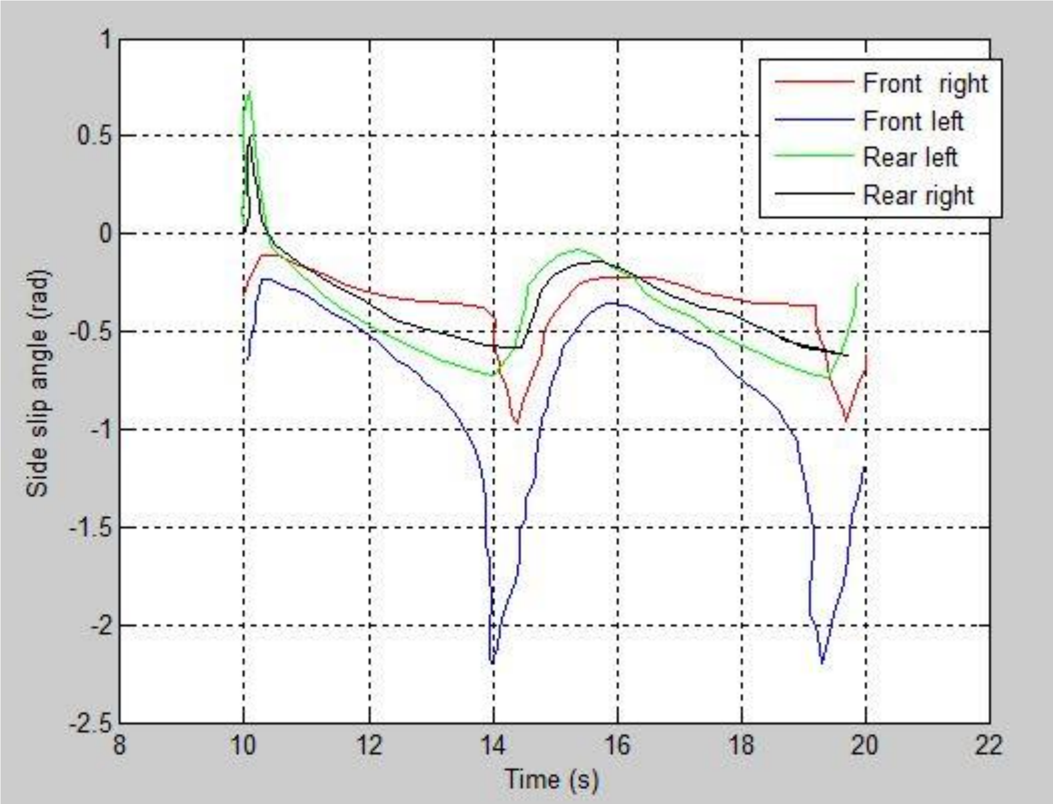
Results:

In this graph, turn radius = 2m; velocity =6m/s



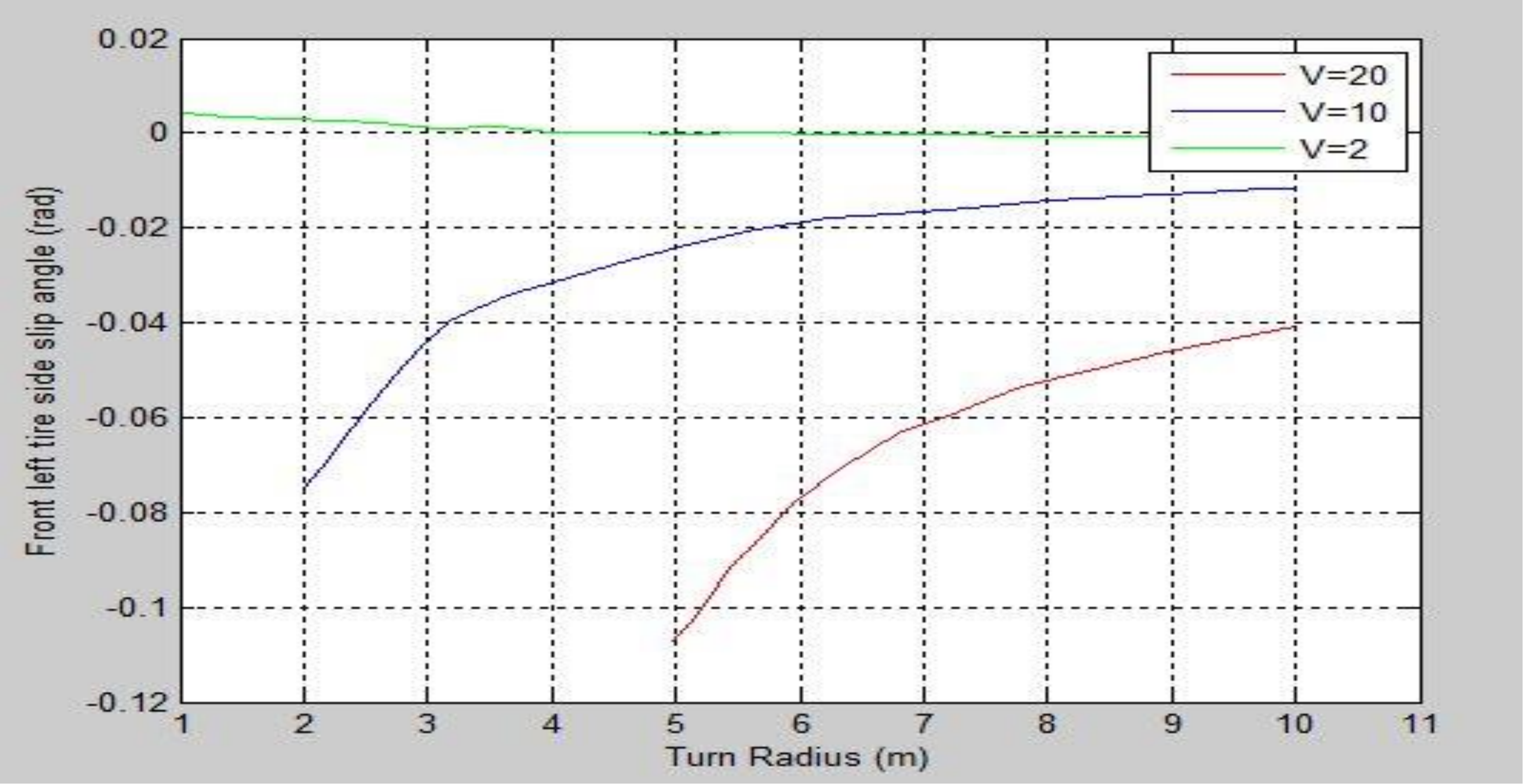
Simulated result

In this graph , turning radius = 2 m; velocity = 14 m/s

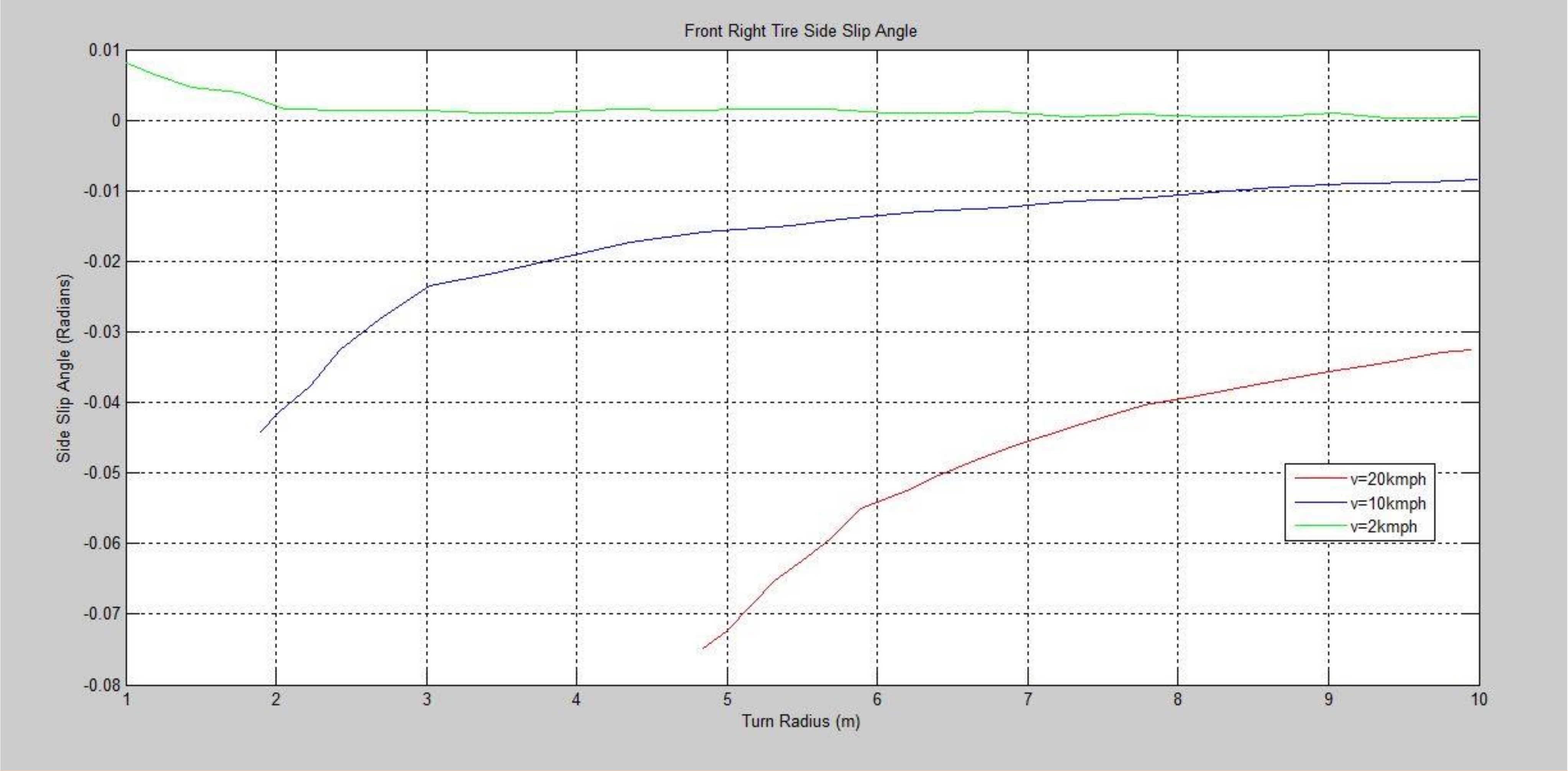


Simulated Result

Comparison of slip angles at different velocities

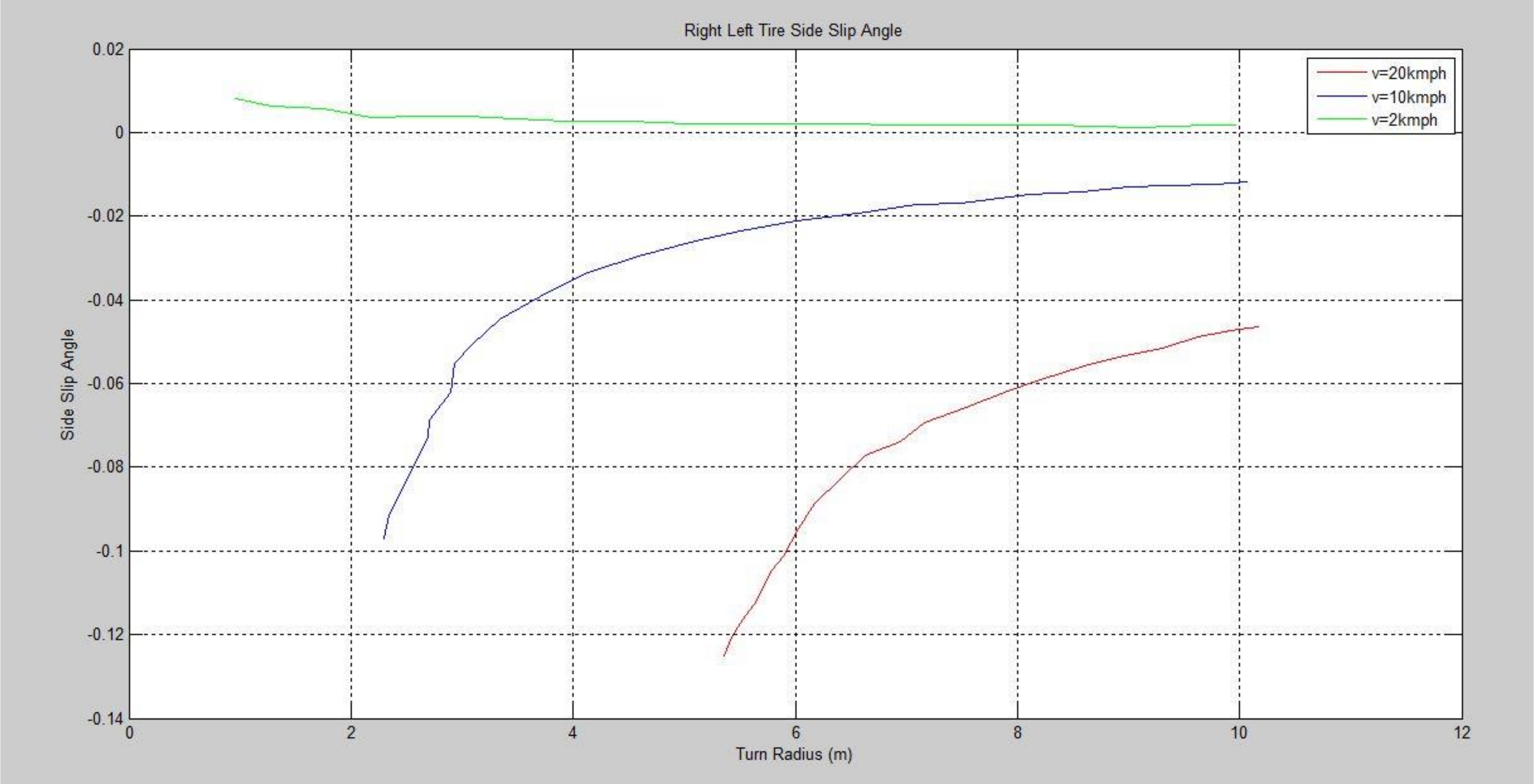


Front Right



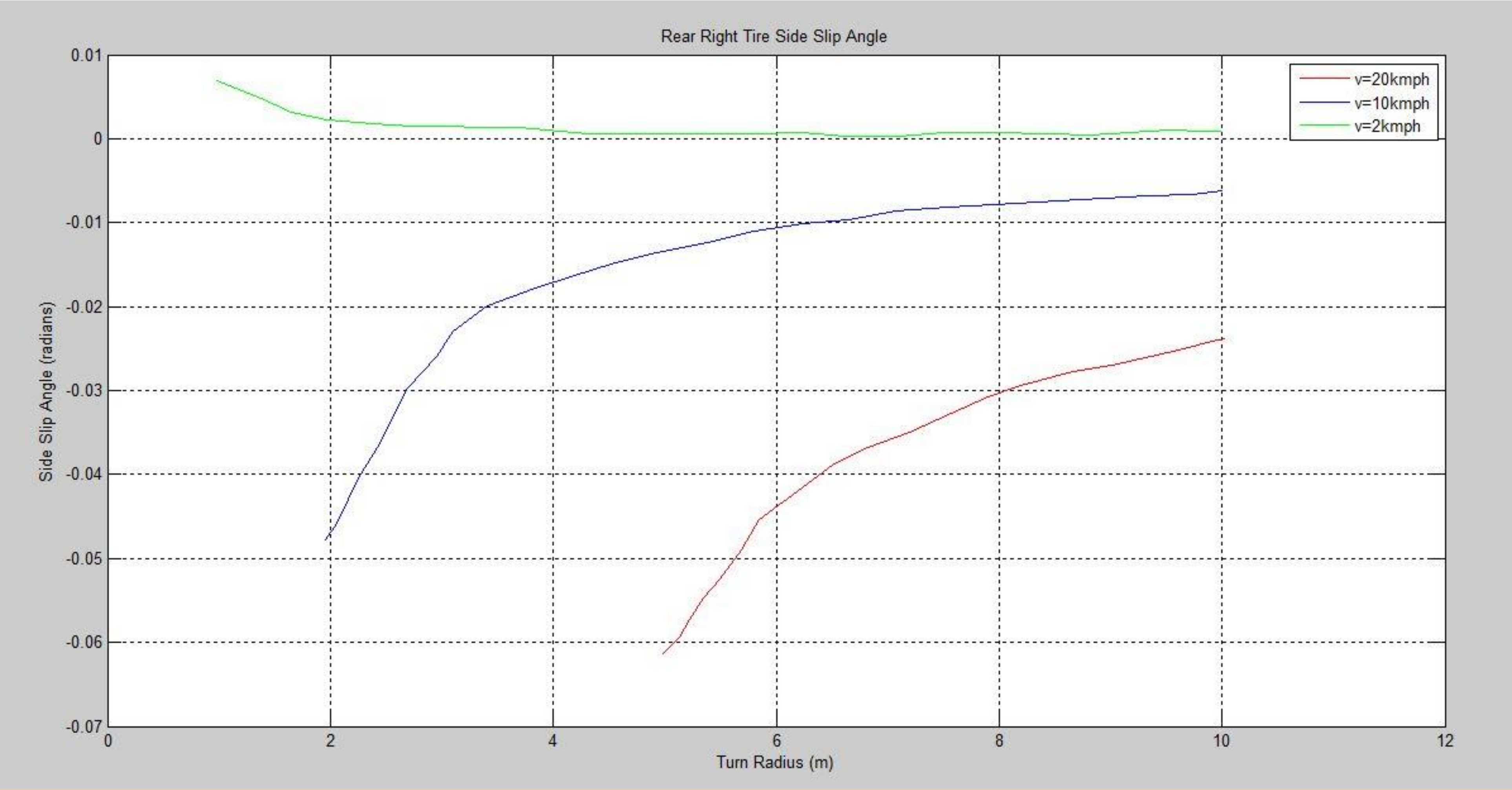
Front Right Tire Side Slip Angle
Side Slip Angle (Radians)
Turn Radius (m)
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
1
2
3
4
5
6
7
8
9
10
v=20kmph
v=10kmph
v=2kmph

Rear Left



Right Left Tire Side Slip Angle
Side Slip Angle
Turn Radius (m)
v=20kmph
v=10kmph
v=2kmph
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
-0.12
-0.14
0
2
4
6
8
10
12

Rear Right



Rear Right Tire Side Slip Angle
v=20kmph
v=10kmph
v=2kmph
Side Slip Angle (radians)
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
0
2
4
6
8
10
12
Turn Radius (m)

Conclusions:

- As velocity increases , the stability of the vehicle decreases.
- This trend is also observed in each wheel of the vehicle.
- For a particular velocity , side slip angle decreases with increase in turn radius.
- To improve the side slip angle response , a PID controller can be used in modelling.

References

- Bouyan Li-“Modeling dynamic stability analysis and control of an omni directional road vehicle” – University of Wollongong-2012.
- www.mathworks.com