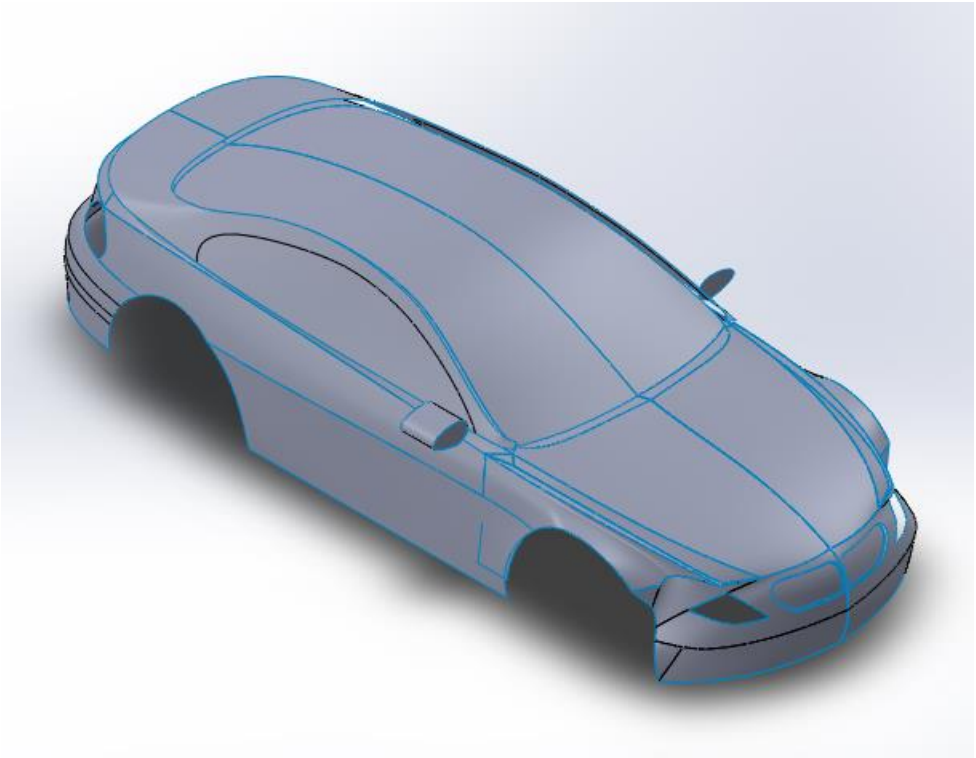
Modelling and analysis of Vehicle Cornering

Group-C

Solid model of car



Low Speed Turning

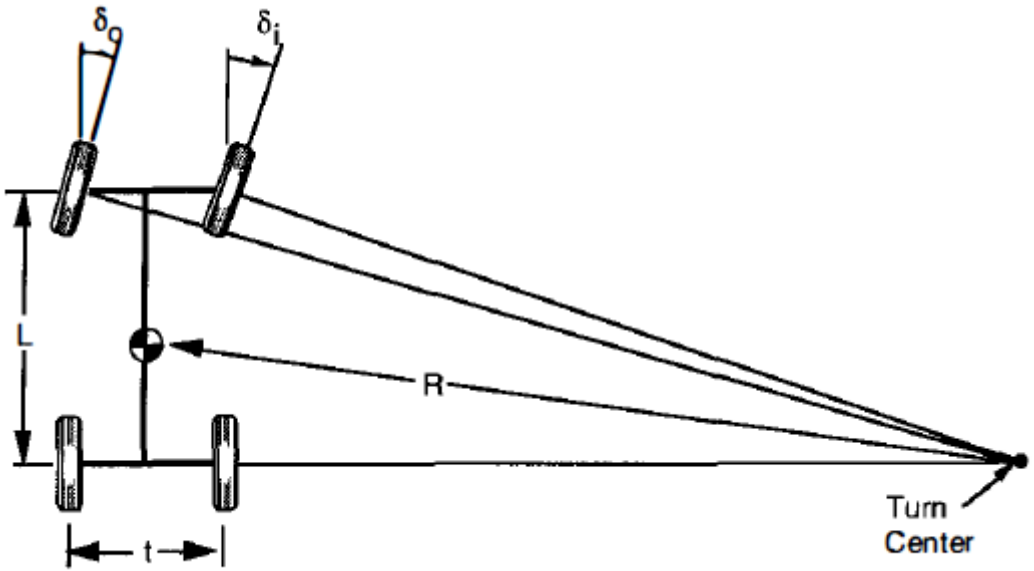
At low speed cornering conditions tyres need not develop lateral forces. So they roll up with zero slip angle

The average steer angle of front wheel also called as ackerman angle($\boldsymbol{\delta}$)

$$\boldsymbol{\delta}=L/R$$

L-distance between front and rear axle

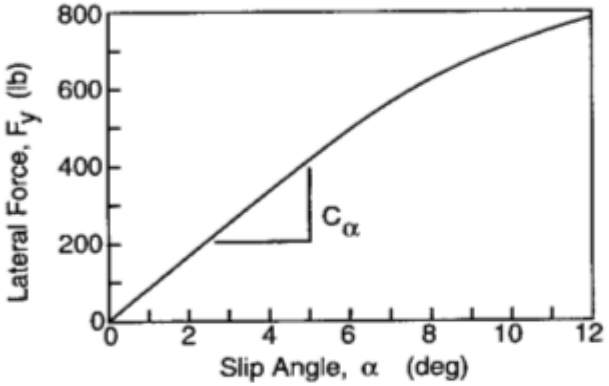
R-radius of turning

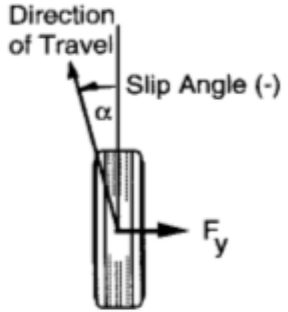

δo
δi
L
R
t
Turn
Center

Tire Cornering Forces

Under high speed cornering lateral forces develops. So the relation between

Lateral force and slip angle is



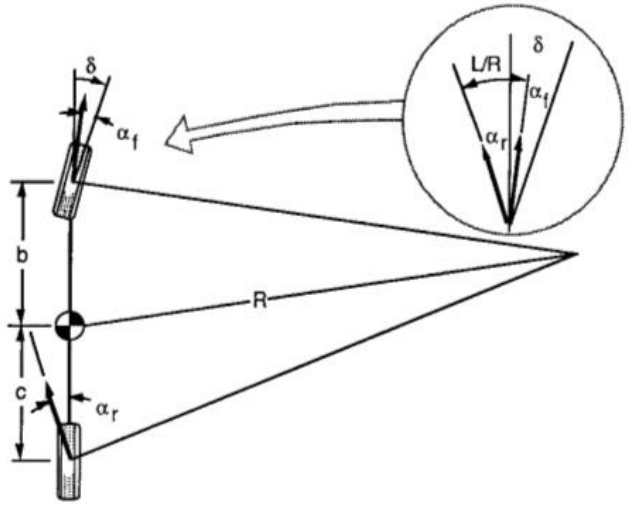


$$F_y = C_\alpha \alpha$$

Tire Cornering Forces

The sum of the lateral forces on front and rear wheels is equal to mass times

Centripetal acceleration



$$\Sigma F_y = F_{yf} + F_{yr} = M\,V^2/R$$

$$F_{yr} = M\,b/L\,(V^2/R)$$

$$F_{yf} = F_{yr}\,c/b$$

$$\delta_f = \frac{L}{R} - \alpha_f + \alpha_r$$

$$F_{yf} = -C_f \alpha_f \qquad F_{yr} = -C_r \alpha_r$$

$$\delta_f = \frac{L}{R} + \left[\frac{F_{yf}}{C_f} - \frac{F_{yr}}{C_r} \right]$$

$$K_{us} = \frac{F_{zf}}{C_f} - \frac{F_{zr}}{C_r}$$

$$\delta_f = \frac{L}{R} + K_{us} \frac{u^2}{Rg}$$

K- Under steer gradient

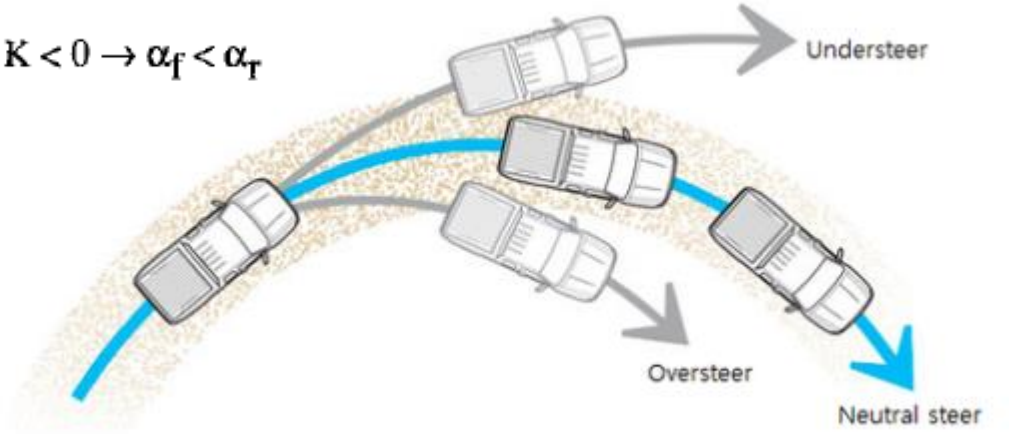
Stability

Neutral Steer: $W_f / C_{\alpha f} = W_r / C_{\alpha r} \rightarrow K = 0 \rightarrow \alpha_f = \alpha_r$

Steer angle is equal to Ackerman angle.

UnderSteer: $W_f / C_{\alpha f} > W_r / C_{\alpha r} \rightarrow K > 0 \rightarrow \alpha_f > \alpha_r$

Oversteer: $W_f / C_{\alpha f} < W_r / C_{\alpha r} \rightarrow K < 0 \rightarrow \alpha_f < \alpha_r$



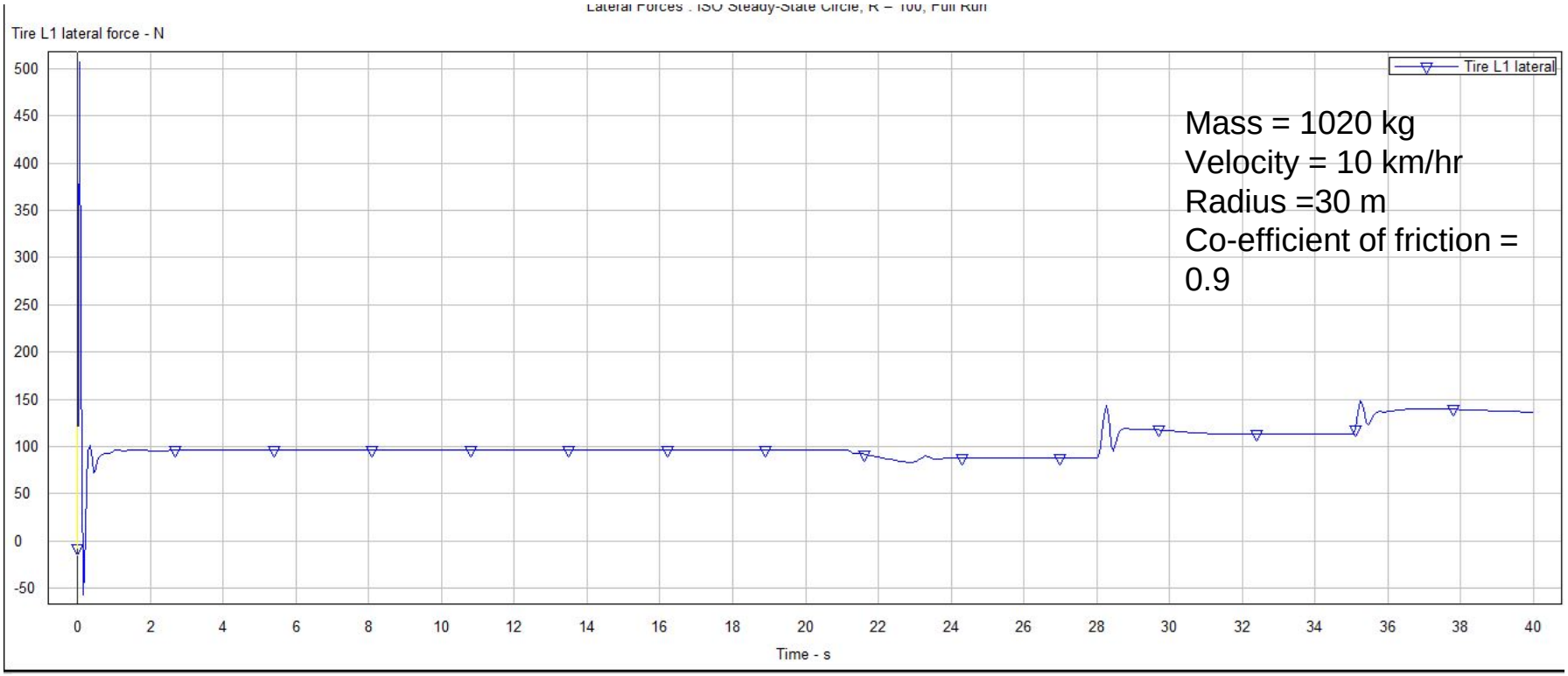
Stability

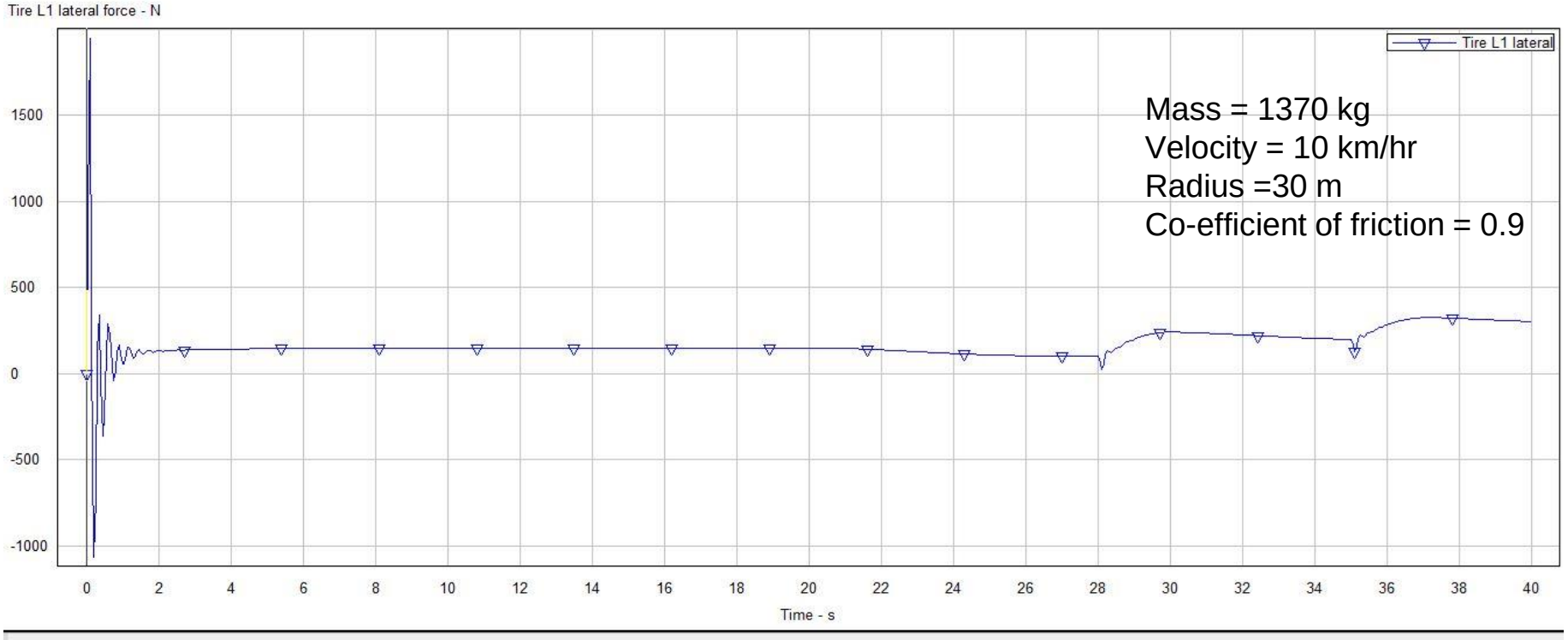
Characteristic Speed: $V_{char} = \sqrt{57.3\ L\ g/K}$

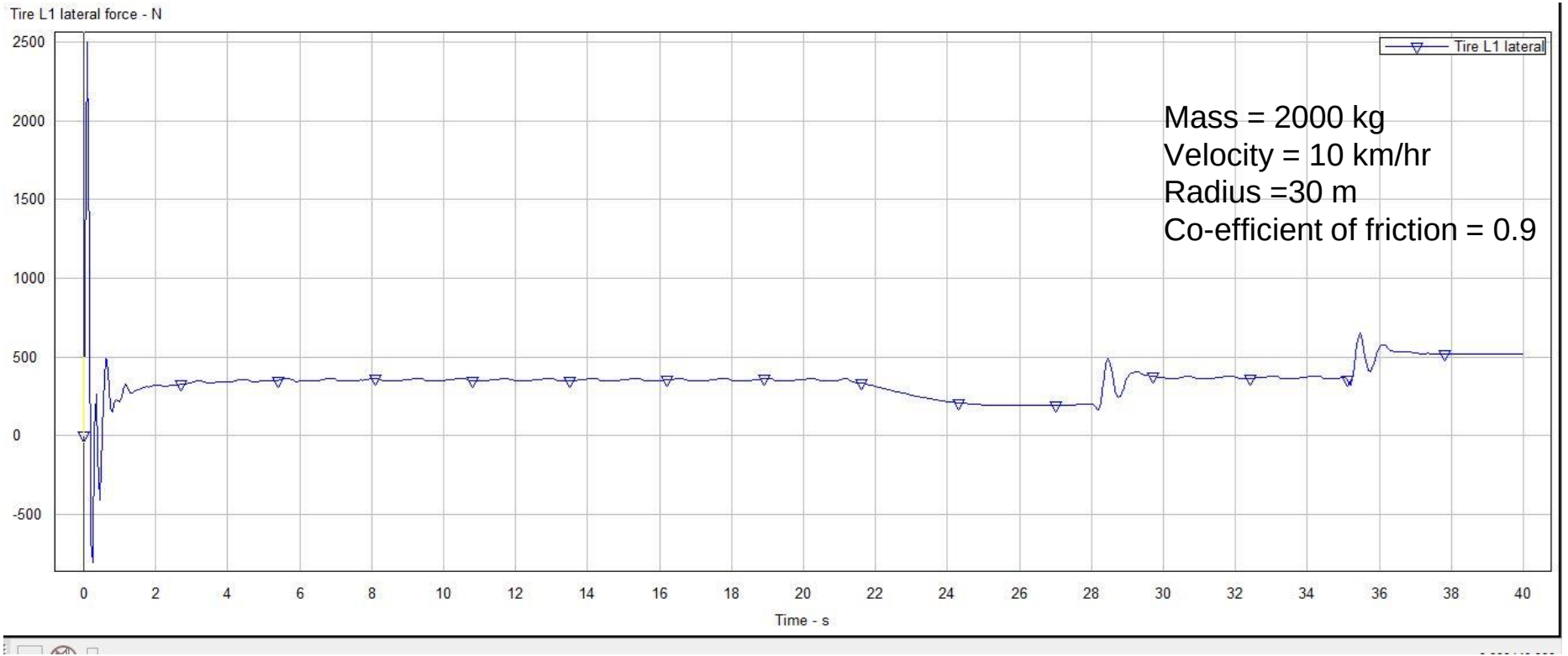
Critical Speed: $V_{crit} = \sqrt{-57.3\ L\ g/K}$

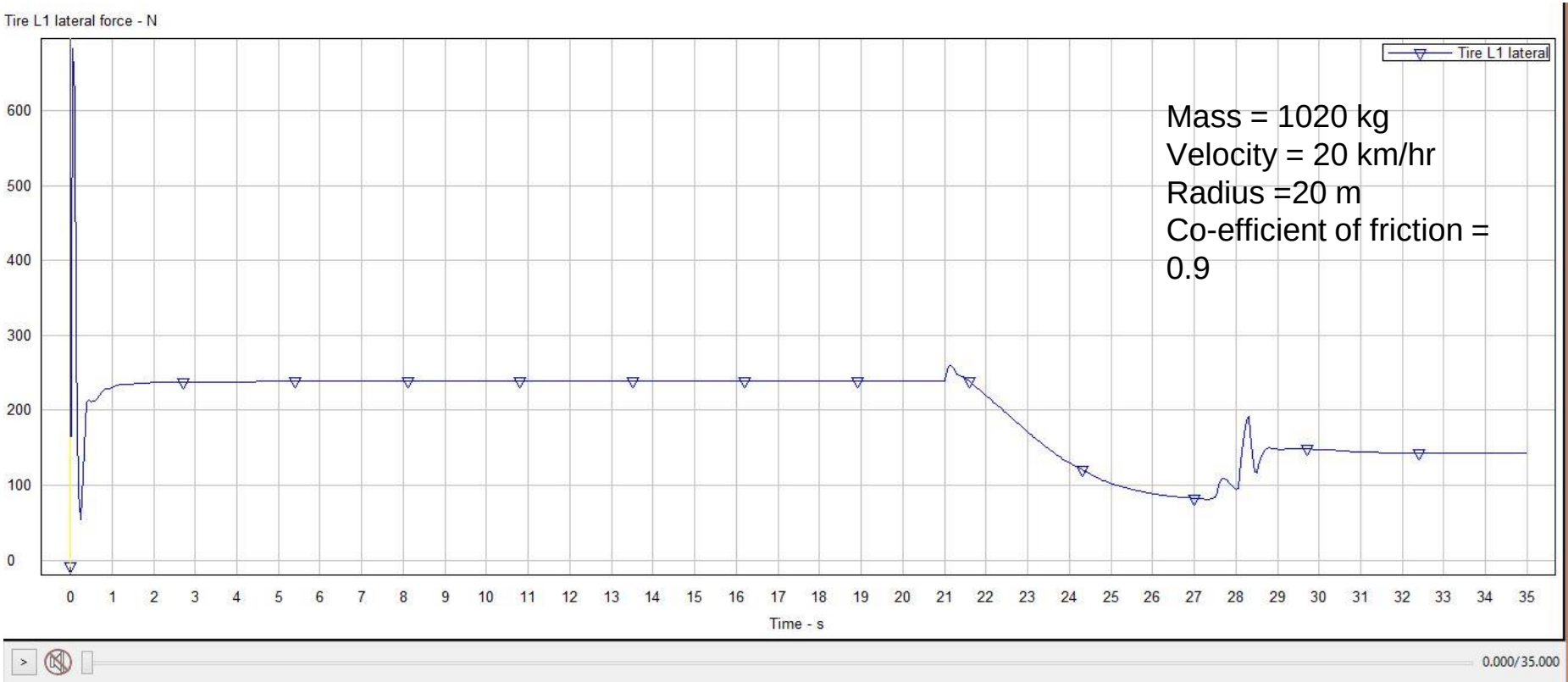
Lateral Acceleration Gain: $$\frac{a_y}{\delta} = \frac{\frac{V^2}{57.3\ L\ g}}{1 + \frac{K\ V^2}{57.3\ L\ g}}$$

CarSim simulation

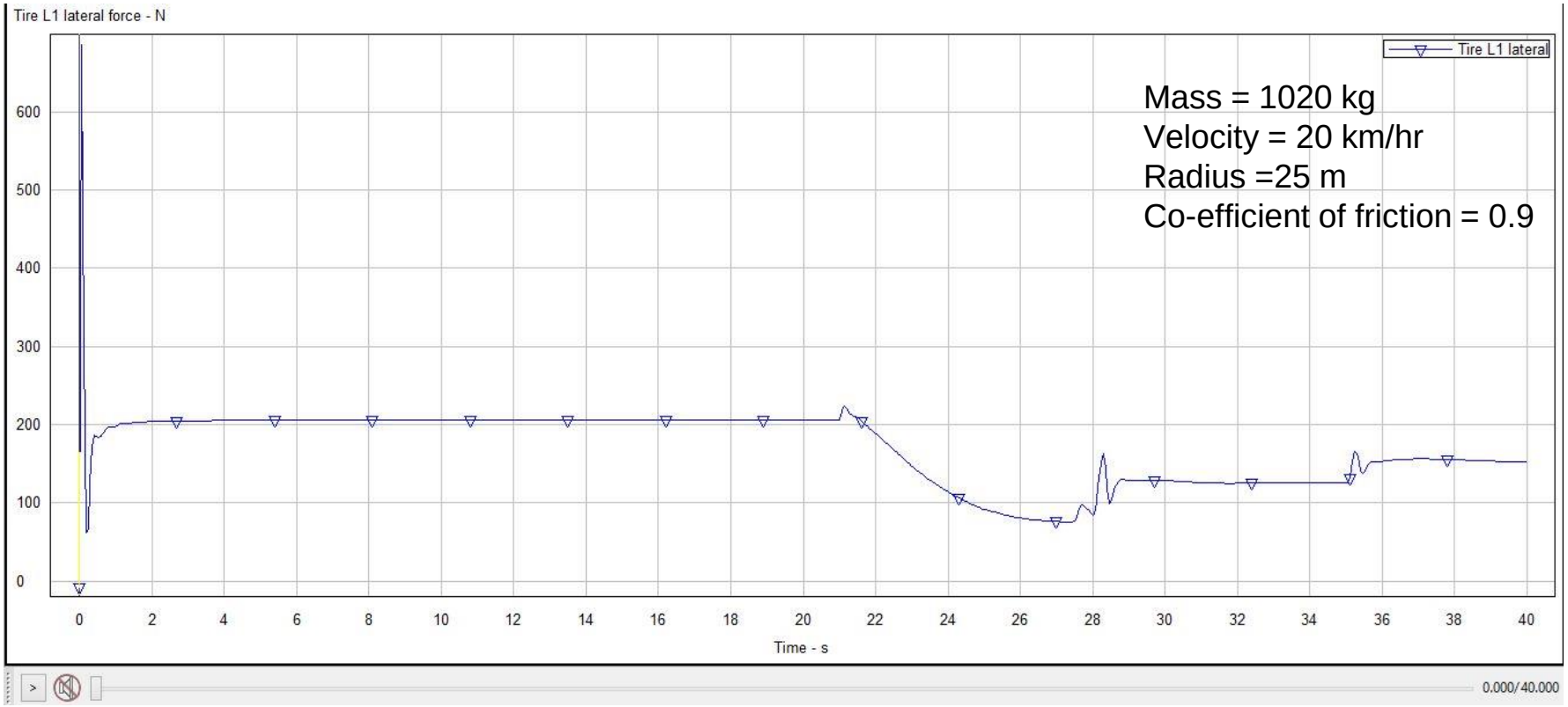

Lateral Forces : ISO Steady-State Circle, R = 100, Full Run
Tire L1 lateral force - N
Tire L1 lateral
500
450
400
350
300
250
200
150
100
50
0
-50
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
Time - s
Mass = 1020 kg
Velocity = 10 km/hr
Radius =30 m
Co-efficient of friction = 0.9

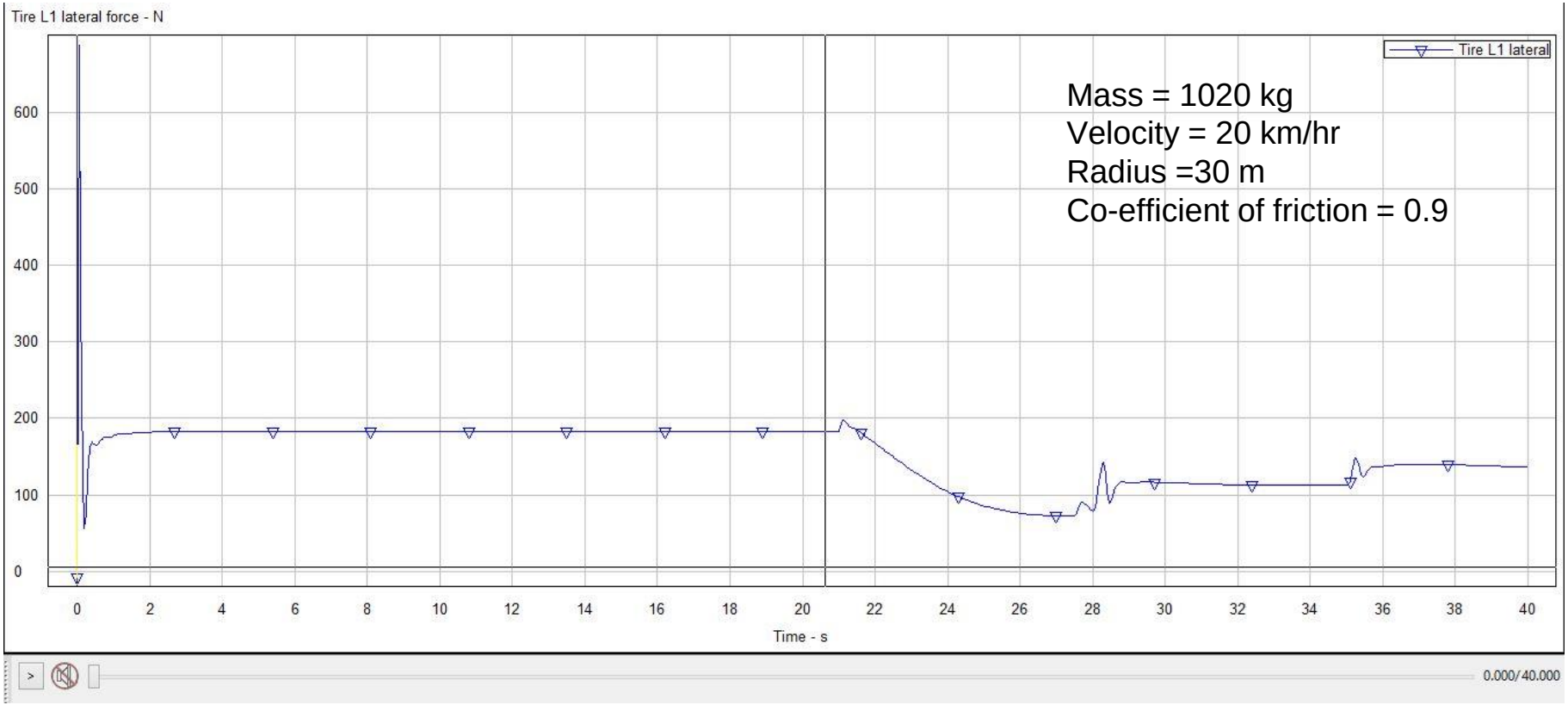

Tire L1 lateral force - N
Tire L1 lateral
1500
1000
500
0
-500
-1000
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
Time - s
Mass = 1370 kg
Velocity = 10 km/hr
Radius =30 m
Co-efficient of friction = 0.9

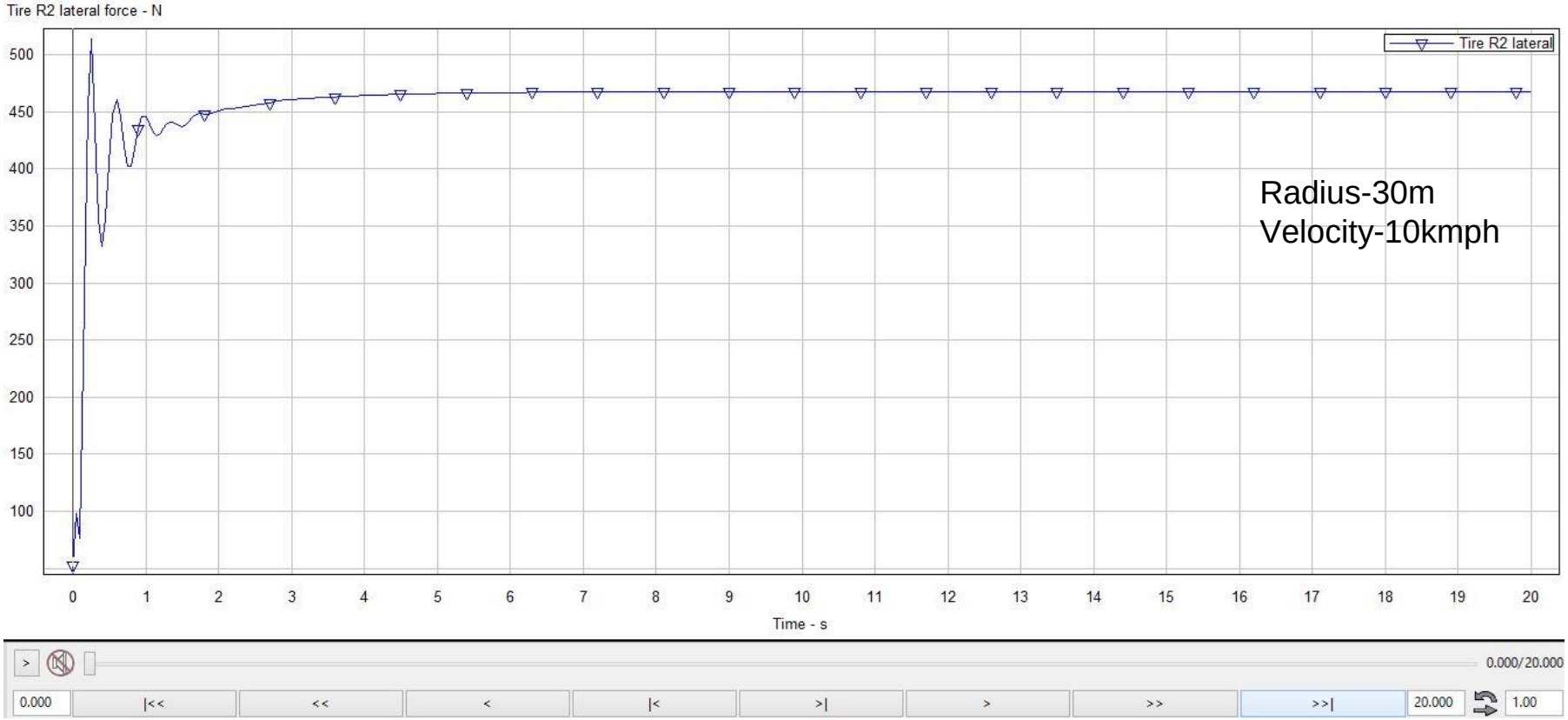

Tire L1 lateral force - N
Tire L1 lateral
2500
2000
1500
1000
500
0
-500
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
Time - s
Mass = 2000 kg
Velocity = 10 km/hr
Radius =30 m
Co-efficient of friction = 0.9

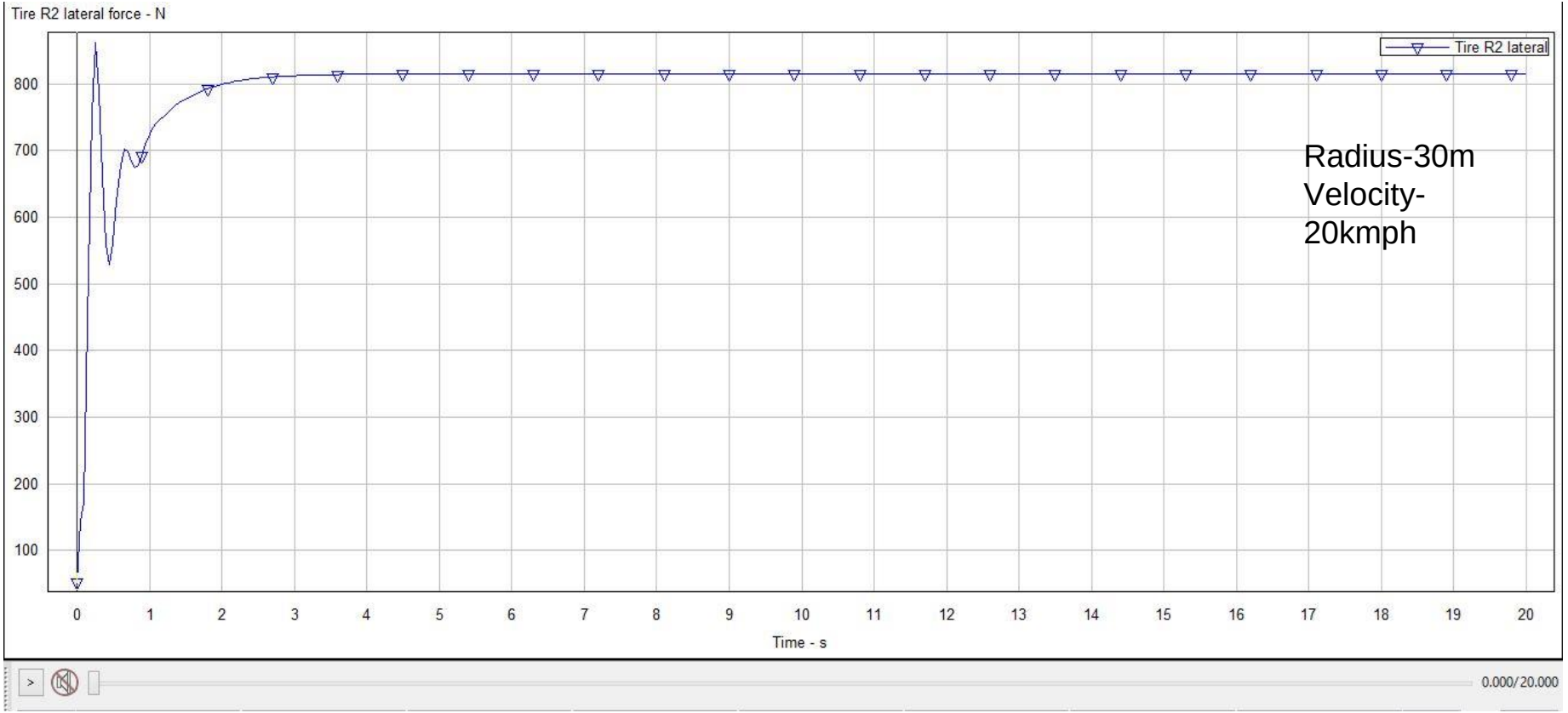


Mass = 1020 kg
Velocity = 20 km/hr
Radius =20 m
Co-efficient of friction = 0.9


Tire L1 lateral force - N
Tire L1 lateral
Mass = 1020 kg
Velocity = 20 km/hr
Radius =25 m
Co-efficient of friction = 0.9
600
500
400
300
200
100
0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
Time - s
0.000/40.000


Tire L1 lateral force - N
Tire L1 lateral
Mass = 1020 kg
Velocity = 20 km/hr
Radius =30 m
Co-efficient of friction = 0.9
600
500
400
300
200
100
0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
Time - s
0.000/40.000


Tire R2 lateral force - N
Tire R2 lateral
500
450
400
350
300
250
200
150
100
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Time - s
Radius-30m
Velocity-10kmph
0.000/20.000
0.000
|<<
<<
<
|<
>|
>
>>
>>|
20.000
1.00


Tire R2 lateral force - N
Tire R2 lateral
800
700
600
500
400
300
200
100
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Time - s
Radius-30m
Velocity-
20kmph
0.000/20.000

Tools and References

- ✓ CarSim
- ✓ Solidworks
- ✓ Vehicle Dynamics by Thomas D Gillespie

Thank You!!