**Abbreviations used for ease:**

Non-linear bicycle model: NLBM

Linear bicycle model: LBM

Kinetic bicycle model: KBM

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3a)



Figure 1: Linear and nonlinear tire force over the slip angle for front tire force



Figure 2: Linear and nonlinear tire force over the slip angle range for rear tire

3b)

Non-linear bicycle model in Simulink file. It’s X\_Y diagram is shown below:

A picture containing chart

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Figure 3: X-Y Diagram of Non-linear bicycle model

3c)

Sinusoidal with v\_lon = 5 m/s

x0 = 0 ;

y0 = -0.1;

Chart, line chart

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Figure 4: NLBM

Chart, line chart

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Figure 5: KBM

Chart, line chart

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Figure 6: Comparison of LBM and NLBM forces

Chart, line chart

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Figure 7: Comparison of LBM and NLBM forces

Sinusoidal with v\_lon = 10 m/s

x0 = 0 ;

y0 = -0.1;

Graphical user interface, chart, line chart

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Figure 8: NLBM

Graphical user interface, chart, line chart

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Figure 9: KBM

Chart, line chart

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Figure 10: Comparison of LBM and NLBM forces

Chart, line chart

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Figure 11: Comparison of LBM and NLBM forces

Sinusoidal with v\_lon = 20 m/s

x0 = 0 ;

y0 = -0.1;

Chart, line chart

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Figure 12:NLBM

Graphical user interface, chart, line chart

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Figure 13: KBM

Chart, line chart

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Figure 14: Comparison of LBM and NLBM forces

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Figure 15: Comparison of LBM and NLBM forces

It can be concluded from X-Y graph in figure 4 & 5, 8 & 9 and 12 & 13 at high longitudinal velocities the non-linear bicycle model deviates from KBM.

From figure 6, 7, 10, 11, 14 and 15 that as the longitudinal velocity increases the difference in LBM and NLBM front tire lateral forces is larger as compared to the rear tire lateral forces.

3d)

V\_lon = 5 m/s

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Figure : X-Y diagram at given v\_lon.

V\_lon = 15 m/s

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Figure : X-Y diagram at given v\_lon.

V\_lon = 30 m/s

Chart, line chart

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Figure : X-Y diagram at given v\_lon

As we increase the value of longitudinal velocity the radius increases.

As compared to linear and kinematic bicycle model for same vale of delta, non-linear bicycle model requires larger radius.