Logo, company name

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**REPORT VEHICLE’S DYNAMICS**

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**Abstract**

The following report analyse the difference between maneuver given different steering input (step steer, ramp steer, and sweep sine), various positions of the Centre of Gravity, and values of speed. All the analysis were performed using a simplified Simulink lateral dynamic model reduced to a bicycle model, where the front wheels are considered a single wheel, same idea for the rears.

**Model used for the simulation**

**Diagram

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The chosen dynamic equation was with the states and input , the reason lies on the complexity of the output equation and on the derivative and handling of .

Figure Steady space model

The state matrices are:

with the following matrices for the output {y} =( .

Considering

* The lateral acceleration was computed while at steady state due to the low value of lateral velocity and its derivative, which can be neglected if compared to the longitudinal speed.
* We imposed some constraints for and (below 1 time the gravitational acceleration), which needed for control purposes and safety of the passengers.
* aside for the understeering gradient, the sign of the slip angle was considered to understand if during the simulation the vehicle speed , behaviour, and model were correct.
* was never reached, furthermore it was only computed for the oversteering case.
* With growing V 🡺 increase 🡺 both increased

**Manoeuvre condition upon position of the CoG**

|  |  |
| --- | --- |
| Static load distribution (%F - %R): | 54-46 |
| Axle cornering stiffness | CF = 187113.8666 N/rad  CR = 169035.7601 N/rad |
| Understeering gradient |  |
| Tangent speed |  |

**Understeering**

Chart, line chart

Description automatically generatedUndersteer occurs when a car is steering less than the amount commanded by the driver, moreover the front-end slip angle is higher than the rear slip angle . The Understeering gradient is positive, from the plot of lateral acceleration versus difference of steering angle, the slope is positive as well meaning that the sign was correct.

|  |  |
| --- | --- |
| Static load distribution (%F - %R): | 50-50 |
| Axle cornering stiffness | CF = 178372.8905 N/rad  CR = 178372.8905 N/rad |
| Understeering gradient |  |
| Tangent speed |  |

Figure 2 K\_us behaviour

**Neutral**

Chart, bar chart

Description automatically generatedThe neutral position has the understeering gradient , the behaviour of at steady state because the load distribution is equal.

Figure 4 K\_us behaviour

|  |  |
| --- | --- |
| Static load distribution (%F - %R): | 46-54 |
| Axle cornering stiffness | CF = 178372.8905 N/rad  CR = 178372.8905 N/rad |
| Critical speed |  |
| Understeering gradient |  |
| Tangent speed |  |

**Oversteering**

During the oversteering maneuver the rear slip angle is higher than the front-end slip angle. The rear end will swing away from the direction the car was turning, pointing the front of the car further into the direction it was turning. The Understeering gradient is negative, because . The critical speed was never reached with the parameters of the vehicles and the inputs.

**Chart, line chart

Description automatically generated**

Figure 5 K\_us behaviour

**Step steering input**

1. **Steering pad (**

**-**General considerations

Graphical user interface

Description automatically generatedMain point of concerns was the tyre slip angles, the slip angles and the yaw rate. Considering that both tyre slip angles increase with the speed for every CoG position, with for the understeering , for the neutral position and for the oversteer, independently from the maneuver.

Chart

Description automatically generated

Chart

Description automatically generated

Figure 9 Neutral at 100 km/h

Figure 7 Understeering at 20km/h

Chart

Description automatically generated

Figure 8 Understeering at 100 km/h

Graphical user interface, application, Excel

Description automatically generatedGraphical user interface, application

Description automatically generated

Figure 12 Understeer slip angle at 150km/h

Figure 11 Slip angle at 100km/h

Figure 10 Slip angle at 20km/h

The speed threshold before an unstable condition was around , where the slip angle diverges till the reaching of the max slip angle when the simulation stops due to a blocking imposed in the model to respect a real situation.

Chart

Description automatically generated

Figure 13 Oversteer trye slip angles at 100km/h

**2. Constant speed**

-General considerations

With a constant speed and a variable steering angle, the results were the following:

* If the speed was low enough , with high value of the vehicle was controllable.
* Slight variation of the steer angle (has a high impact at high speed ( and the controllability of the vehicle.

Chart

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Figure 16 V= 100km/h, steer angle 20° for tyre slip angles for Oversteer.

Figure 15 V= 100km/h, steer angle 20° for tyre slip angles for Understeer

Figure 14 V=60km/h and steer angle 60°, slip behaviour

Chart, line chart

Description automatically generatedChart, line chart

Description automatically generatedChart, line chart

Description automatically generated

Figure 17 Slip behaviour at V=100km/h and delta >30

While in the stable conditions the yaw rate was constant, it was not the case in the unstable conditions where it should be saturate to a maximum value to allow the vehicle to be controlled

Figure 19 Tyre slip angle at V=100km/h and delta >20, Oversteer

Figure 18 Tyre slip angle at V=100km/h and delta >20, Understeer

( .

**Ramp steering input**

1. **Constant steer angle (**

-General considerations

With a constant steer angle the output of all three kind of behaviour is the same, at the vehicle is unstable for every position of the CoG.

Test at different speed showed that:

* under the vehicle was stable, with a slip angle below the maximum value imposed of 10° and yaw rate with maximum value at 30°/s
* At the value of reaches 13°/s

Chart, line chart

Description automatically generatedChart, line chart

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Figure 21. Tyre slip angles at V= 30 km/h for Oversteering

Figure 22 Tyre slip angle at steer angle 20° with V=100 km/h for Understeering.

Figure 20. Slip angle at V= 30 km/h

Chart, line chart

Description automatically generatedChart, line chart

Description automatically generated

Chart, line chart

Description automatically generated

Figure 24 Unstable condition of tyre sip angles at 20° with V=100 km/h

Figure 23 Unstable condition at 40km/h

Figure 25 Unstable condition for understeering with slip angle 60° with V=60 km/h

1. **Constant speed (**

-General considerations

With fixed speed there were the following results:

* If constant and the vehicle becomes unstable
* If constant, the vehicle is unstable from

Chart, line chart

Description automatically generatedChart

Description automatically generated with low confidence

Figure 27 Unstable condition with speed over 40 km/h

Figure 26. Stable condition with speed at 30 km/h and delta 150°

**Sweep sine input**

Simulates a vehicle driving at a constant speed with a sinusoidal steering input of constant magnitude but increasing frequency applied, in the simulation case those were 0.05, 0.5, 5 Hz.

-General consideration

* High frequencies 🡺 fastest response of , and

🡺 convergences of the outputs for t>25s

🡺 higher than for all cases after 5s

Chart, histogram

Description automatically generatedChart, diagram

Description automatically generatedTimeline

Description automatically generated with medium confidence

Figure 28 Tyre slip angle at 5Hz for Understeering

Figure 29 Slip angle at 5Hz for Understeering

Figure 30 at 5Hz for Understeering

Graphical user interface, chart, line chart, histogram

Description automatically generatedA picture containing graphical user interface

Description automatically generated

Figure 32 Tyre slip angle at 0.05Hz for Understeering

Figure 31 Tyre slip angle at 0.5Hz for Understeering

Chart, line chart

Description automatically generatedChart, line chart

Description automatically generatedGraphical user interface, chart

Description automatically generated

Figure 33 Slip angle at 0.05Hz for Understeering

Figure 34 Oversteering at 0.05Hz

Figure 32 Tyre slip angle at 0.05Hz for Understeering