A Simulation Study of the Effects of Road Undulations, ABS and Driving Dynamics on Handling Performance of Tire

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Abstract

Now a days, a good handling performance of vehicle is uttermost important as it directly relates to the safety of the vehicle. A good handling vehicle should be easily controllable and stable enough even under the adverse conditions of braking in a turn, sudden frictional changes, sudden steering inputs etc,. Handling performance of a vehicle is mainly dominated by tire forces, which are generated due to viscoelastic deformation of the tire. These forces play a crucial role in guiding, controlling and stabilizing the vehicle. The driver controls these forces indirectly by inducing steering or braking input. The different operating handling regimes of the vehicle are [1]:

1. Linear, low lateral acceleration (< 0.2 g)
2. Transient, lateral acceleration (0.2 – 0.35 g)
3. Non-linear, up to limiting lateral acceleration (~= 0.8 g) with combined cornering, braking and acceleration maneuvers.

In the linear handling region, a simple magic formula based tire model can be used for these studies, as the main tire parameters effecting the performance are tire cornering stiffness, tire size and tire pressure in front and rear. For studying the transient and nonlinear handling performance of the vehicle, the variations of tire stiffness and damping parameters, relaxation length of tire and tire inertial effects play a significant role [2]. To characterize the transient and nonlinear handling performance of the tire, an independent objective handling metrics which are more tire dependent and driver sensitive has to developed.

The goal of this study is twofold, one is to understand the nonlinear effects of ABS, road undulations and driving dynamics on lateral performance of tire and other is to develop objective handling metrics to characterize these effects on the vehicle behaviour. A high frequency (< 75 Hz) 6 DOF dynamic tire model integrated with enveloping model, which is validated in previous studies [3,4] is used. The developed tire model is integrated with Carsim to perform various objective simulations and for evaluation of handling performance of the tire.

Based on the ISO/SAE standards, the following simulation conditions are selected to study each effect.

Road Undulations:
Constant Radius (100 m) with linearly accelerating from 20 – 80 kph in time = 8 sec on

I. Smooth road with no undulations
II. Short wavelength road profile

In this case, effect of road undulations on transient handling performance of the vehicle is studied. For not inducing any excessive disturbance in the form of steering inputs, a preview time of 0.5 seconds and driver delay time of 0.1 seconds were used, representing an experienced driver. To study the transient handling performance on smooth and rough roads, slope of roll angle and steering wheel angle vs lateral acceleration and understeer coefficient curves are selected. As the transient dynamics of vehicle is predominate in between 0.2 – 0.35 g of lateral acceleration, these gradients are calculated in this range. From the simulations, it is observed that the tire lateral inertial vibrations are induced due to road undulations and are eventually causing gradient values to increase when compared with the behavior on smooth road.

ABS:

Usually, the vehicles are inherently understeer and the tendency of drivers in a turn is to apply brake or release accelerating pedal and control steering. To study the behavior of vehicle while braking in a turn, ISO 4138 standard maneuver of braking on constant radius (100 m) from an initial speed of 80 kph is selected. From this study, it is demonstrated that after the activation of ABS, behaviour of vehicle is changed from steady state to highly nonlinear condition and the handling performance of vehicle has become very worse. Due to load transfer in constant radius turn, available tractive force at left and right side of vehicle is unequal. So the fast cyclying unequal ABS braking inputs on left and right side of the vehicle induces a continuous disturbance in yaw rate of the vehicle. This causes the vehicle to severely understeer. Thsi resulted in the excitation of lateral and longitudinal inertial modes of the tire due to disturbance in the yaw rate of the vehicle and fast cycling ABS pressure pulse inputs.

Driving Dynamics:

Constant Radius (100 m) with a constant speed of 80 kph

I. Preview time = 0.7 sec, Driver Delay = 0.1 sec (like an experienced driver)
II. Preview time = 0.7 sec, Driver Delay = 0.25 sec (like a novice driver)

For characterizing the effect of disturbance in steering inputs on handling performance of the vehicle, an experienced and novice driver models are considered. For this study a higher delay in reaction time to changing road conditions is considered for novice driver. ISO 4138, constant radius maneuver at a constant speed is performed. From the simulation it is observed that, the novice driver is inducing disturbance by continues correction of steering angle inputs. As the vehicle is operating at higher lateral accelerations and also due to lower vertical load on inside tires, these disturbance from steering angle inputs are exciting the lateral inertial modes of the tire and eventually driving the vehicle towards instability.

From these simulation results it has demonstrated the importance of tire dynamic effects and its significance influence on handling performance of vehicle.

References

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