

MODELING AND SIMULATION OF 14 DOF VEHICLE DYNAMICS

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I/We admit that have read this report and in my/our opinion, this report is enough in terms of scope and quality to bestowal Bachelor of Mechanical Engineering (Automotive)

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I declare that this report is my own work except for any summary or quotation from every single source is explained.

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Date : 10 APRIL 2009

For my beloved mother, and family

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ABSTRACT

An accurate vehicle model is important to represent the behavior of the vehicle. There are many vehicle models built for the study of the vehicle dynamics specifically for the ride and handling behavior. This project describes the vehicle model development of the vehicle model to study the behavior of the vehicle. The derivation of a 14 DOF vehicle model consisting of ride, handling and tire model is presented. Three types of tire model namely Calspan, Dugoff and Magic Formula is developed in the Simulink and their performance for longitudinal force, lateral force and aligning moment was investigated and compared with the CarsimEd outputs. The most accurate tire model which follows the output of the CarSimEd was chosen to be coupled with the 14 DOF model. All the assumptions made for the 14 DOF vehicle model is stated. This 14 DOF vehicle model will be then validated using instrumented vehicle for two steering inputs namely step steer, and double lane change. The deviation of the outputs specifically the yaw rate, lateral acceleration and roll angle of the vehicle body and also the slip angle at each of the tire from the 14 DOF model simulation from the experimental results is discussed.

ABSTRAK

Suatu model kenderaan yang tepat adalah penting untuk mewakili kelakuan sesuatu kenderaan. Terdapat banyak model kenderaan yang dihasilkan bertujuan untuk mempelajari dinamik kenderaan terutamanya kelakuan tanggungan dan pengendalian. Projek ini menerangkan tentang pembangunan model kenderaan untuk mempelajari kelakuan kenderaan. Pengembangan untuk model kenderaan dengan 14 darjah kebebasan mengandungi model tanggungan, pengendalian, dan model tayar ditunjukkan. Tiga jenis model tayar iaitu Calspan, Dugoff dan Magic Formula telah dibangunkan dalam Simulink dan prestasi untuk daya dalam arah x dan y dan momen dalam arah z telah disiasat dan akan dibezakan dengan CarSimEd. Model tayar terbaik yang mengikuti response CarSimEd akan dipilih untuk digabungkan dengan model kenderaan 14 darjah kebebasan. Semua andaian untuk model kenderaan dengan 14 darjah kebebasan disertakan dalam projek ini. Model kenderaan dengan 14 darjah kebebasan telah disahkan dengan menggunakan data eksperimen untuk dua jenis pengemudian iaitu pengemudian pemalar dan perubahan dua lorong. Ralat untuk keputusan yang diperolehi melalui simulasi model kenderaan 14 darjah kebebasan berbanding keputusan daripada eksperimen dibincangkan.

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LIST OF SYMBOLS

- a = Distance of sprung mass C.G. from front axle
- a_y = Lateral acceleration
- b = Distance of sprung mass C.G. from rear axle
- C_{sfl} = Front left suspension damping coefficient
- C_{sfr} = Front right suspension damping coefficient
- C_{srl} = Rear left suspension damping coefficient
- C_{srr} = Rear right suspension damping coefficient
- F_{fl} = Front left suspension force
- F_{fr} = Front right suspension force
- F_{rl} = Rear left suspension force
- F_{rr} = Rear right suspension force
- F_{sfl} = Front left spring force
- F_{sfr} = Front right spring force
- F_{srl} = Rear left spring force
- F_{srr} = Rear right spring force
- F_{dfl} = Front left damper force

- F_{dfr} = Front right damper force
 F_{drl} = Rear left damper force
 F_{drr} = Rear right damper force
 F_v = Vertical force on vehicle body
 F_{xfl} = Front left tire longitudinal force
 F_{xfr} = Front right tire longitudinal force
 F_{xrl} = Rear left tire longitudinal force
 F_{xrr} = Rear right tire longitudinal force
 F_{yfl} = Front left tire lateral force
 F_{yfr} = Front right tire lateral force
 F_{yrl} = Rear left tire lateral force
 F_{yrr} = Rear right tire lateral force
 F_{zfl} = Front left tire normal force
 F_{zfr} = Front right tire normal force
 F_{zrl} = Rear left tire normal force
 F_{zrr} = Rear right tire normal force
 h = Height of vehicle C.G. from ground
 h_{rc} = Height of roll center from ground
 I_p = Pitch moment of inertia
 I_r = Roll moment of inertia
 kph = kilometers per hour
 k_θ = Body pitch stiffness

- k_{ϕ} = Body roll stiffness
 K_{sfl} = Front left suspension stiffness
 K_{sfr} = Front right suspension stiffness
 K_{srl} = Rear left suspension stiffness
 K_{srr} = Rear right suspension stiffness
 K_{tfl} = Front left tire stiffness
 K_{tfr} = Front right tire stiffness
 K_{trl} = Rear left tire stiffness
 K_{trr} = Rear right tire stiffness
 l_f = Distance of vehicle C.G. from front axle
 l_r = Distance of vehicle C.G. from rear axle
 m_s = Sprung mass
 m_t = Total mass of vehicle
 m_{ufl} = Front left unsprung mass
 m_{ufr} = Front right unsprung mass
 m_{url} = Rear left unsprung mass
 m_{urr} = Rear right unsprung mass
 M_{zfl} = Front left tire aligning moment
 M_{zfr} = Front right tire aligning moment
 M_{zrl} = Rear left tire aligning moment
 M_{zrr} = Rear right tire aligning moment
 S_{af} = Front tire longitudinal slip

- S_{ar} = Rear tire longitudinal slip
 T_{bfl} = Front left wheel brake torque
 T_{bfr} = Front right wheel brake torque
 T_{brl} = Rear left wheel brake torque
 T_{brr} = Rear right wheel brake torque
 T_{dfl} = Front left wheel drive torque
 T_{dfr} = Front right wheel drive torque
 T_{drl} = Rear left wheel drive torque
 T_{drr} = Rear right wheel drive torque
 V_{tf} = Front tire speed
 V_{tr} = Rear tire speed
 v_{wxf} = Front tire longitudinal velocity
 v_{wxr} = Rear tire longitudinal velocity
 v_x = Longitudinal velocity
 v_y = Lateral velocity
 w = Track width
 Z_{rfl} = Front left road profile
 Z_{rfr} = Front right road profile
 Z_{rrl} = Rear left road profile
 Z_{rrr} = Rear right road profile
 \ddot{Z}_s = Sprung mass vertical acceleration at body C.G.
 Z_{sfl} = Front left sprung mass displacement

- \dot{Z}_{sfl} = Front left sprung mass velocity
 Z_{sfr} = Front right sprung mass displacement
 \dot{Z}_{sfr} = Front right sprung mass velocity
 Z_{srl} = Rear left sprung mass displacement
 \dot{Z}_{srl} = Rear left sprung mass velocity
 Z_{srr} = Rear right sprung mass displacement
 \dot{Z}_{srr} = Rear right sprung mass velocity
 Z_{url} = Rear left sprung mass displacement
 Z_{ufl} = Front left unsprung mass vertical displacement
 \dot{Z}_{ufl} = Front left unsprung mass vertical velocity
 \ddot{Z}_{ufl} = Front left unsprung mass vertical acceleration
 Z_{ufr} = Front right unsprung mass vertical displacement
 \dot{Z}_{ufr} = Front right unsprung mass vertical velocity
 \ddot{Z}_{ufr} = Front right unsprung mass vertical acceleration
 Z_{url} = Rear left unsprung mass vertical displacement
 \dot{Z}_{url} = Rear left unsprung mass vertical velocity
 \ddot{Z}_{url} = Rear left unsprung mass vertical acceleration
 Z_{urr} = Rear right unsprung mass vertical displacement
 \dot{Z}_{urr} = Rear right unsprung mass vertical velocity
 \ddot{Z}_{urr} = Rear right unsprung mass vertical acceleration
 α_f = Front tire side slip angle
 α_r = Rear tire side slip angle