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 keputusn 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 left 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_{srl} = 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