Modeling and simulation the resistance torque for specific wheel alignment in the Electric Power Steering system by using Matlab/Simulink and its application.

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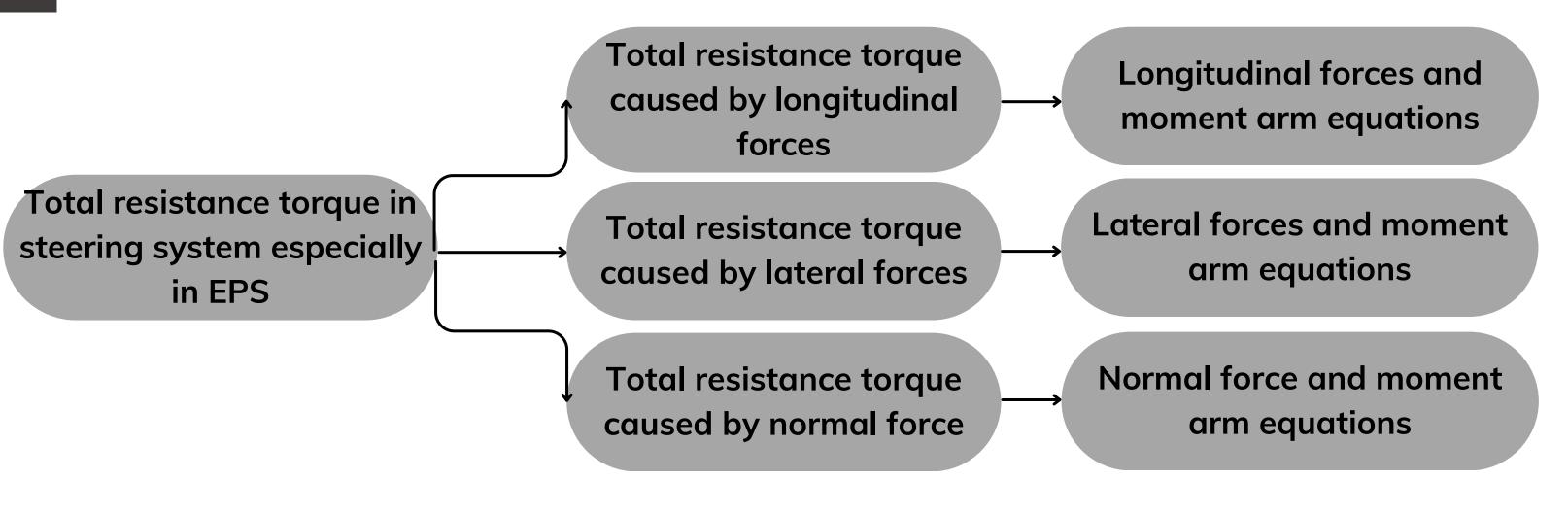
Abstract:

Vehicle steering dynamics is an essential topic in development of safety driving systems. These complex and integrated control units require precise information about vehicle steering dynamics, especially, tire/road contact forces. In the term of interaction between tyre force and road surface, we are going to primarily focus on the total resistance moment which is the factor torque that urges the tyres to steer. This resistance moment that causes this will be described in below when considering the mass of vehicle, wheel alignment, lateral force generation, longitudinal force generation and normal force generation. Through this Capstone project, this torque will be fully showed with the theoretically corresponding equation and combine with the result diagrams by using Matlab/Simulink software.

Objectives, scope and mission summary:

- Objective: focus on building mathematical models and simulations of the magnitude of this resistance torque under different driving conditions.
- Scope: only investigate the effects wheel alignment and specific factor on the total resistance torque.
- Mission summary: base on this scope, I will divide the whole objective into 2 main missions: The first one is get fully understanding knowledge about the resistance torque between the tire force and road surface in steering mechanism especially in the EPS system and the second one is how wheel alignment and other factors can affect to the resistance torque in steering mechanism especially in the EPS system.

General mathematical layout diagram:



Matlab/Simulink modeling: 5 Wheel alignment cos sin and tan Tire radius Sin Right Steer Toral resistance moment by normal force Right Norrmal Force Resistant Torque Calulation by Normal Force $\overline{M_{align}} = F_X \cdot \cos(\tau) [r_{kp} \cdot \cos(\gamma) +$ Resistance moment caused by Longitudinal forces left Scrub radius Resistance moment caused by Longitudinal forces right sin left steer cos left steer cos right steer sin right steer The Resistant Moment by Longitudinal Force **Step 1:** Estimate the total lateral forces: $F_V = F_v \cdot \cos(\delta_i) + (F_v - F_{rolling}) \cdot \sin(\delta_i)$ Cos Kingpin angle otal resistance moment caused by FY left lateral force left Lateral Force right

Calculation process diagram: Caster The moment arm: The resistance torque by FX $d = r_{kp} \cdot \cos(\gamma) +$ $= F_{\chi} \cdot \cos(\tau) [r_{kp} \cdot \cos(\gamma)]$ R_{nom} . $\sin(\gamma)$ $+R_{nom}.\sin(\gamma)$ Lateral force: $Fy = \alpha_f \cdot C_{\alpha_f}$ Stiffness C_{α} The total longitudinal Longitudnal Friction force: coefficient $F_x = \mu_x \cdot F_z$ $= (F_x - F_{rolling}) \cdot \cos(\delta_i)$ $-F_{v}$. $\sin(\delta_{i})$ Wheelbase l Normal force: $F_z = \frac{1}{2} m. g. \frac{1}{2}$ a_2 Sideslip angle α Rolling Gravitational acceleration g $F_r = m.g.f$ Rolling resistance coefficient f Vehicle Caster The moment arm: The resistance torque by FY $d = [(t.\cos(\tau) - t]]$ The total trail t and tire R_{nom} . $\sin(\tau)$ $= F_{\gamma}.\cos(\gamma)[(t.\cos(\tau))]$ Total resistance torque Mz $+R_{nom}.\sin(\tau)$ Lateral force: $Fy = \alpha_f \cdot C_{\alpha_f}$ Stiffness Ca The total lateral force Longitudnal Friction force: coefficient $= F_{v} \cdot \cos(\delta_{i}) + (F_{x})$ $F_x = \mu_x \cdot F_z$ $-F_{rolling)}$. $\sin(\delta_i)$ Wheelbase l Normal force: $F_z = \frac{1}{2} m. g. \frac{1}{l}$ a_2 Sideslip angle α Rolling Gravitational resistance: resistance coefficient f The scrub radius r_{kn} and $= F_z \cdot \sin(\gamma) \cdot \cos(\tau) \cdot \sin(\delta)$ $\{cos(\gamma), [r_kp +$ The total lateral force: $F_Z = (\frac{1}{2} mg \frac{a_2}{l})$ $.\sin(\gamma).\cos(\tau).\sin(\delta)$ Wheelbase i Gravitational acceleration g

Changing in vehicle mass Vehicle mass (kg) Total Resistance Torque at constant steering torque T = 20N.m, speed v = 180km/h, τ = 5° and γ = 9° (N.m. 1100 1150 1200 1250 1300 1350 1400 1450 1500 Total Resistance Torque at constant steering torque T = 20N.m, speed v = 140km/h, $\tau = 5^{\circ}$ and $\gamma = 9^{\circ}$ (N.m) Total Resistance Torque at constant steering torque T = 20N.m, speed v = 100 km/h, $\tau = 5^{\circ}$ and $\gamma = 9^{\circ}$ (N.m. Vehicle mass (kg Vehicle velocity effect on the total resistance torqu Vehicle speed effect on the total resistance torque at The resistance torque distribution on vehicle velocity different vehicle mass 14.55 14.55 14.55 14.55 14.55 14.55 vehicle speed Vehicle speed (km/h) Total Resistance Torque at constant torque T = 20N.m, vehicle mass = 1100kg, $\tau = 5^{\circ}$ and $\gamma = 9^{\circ}$ Kingpin angle effect on the total resistance torque **Changing in** Kingpin vehicle wheel alignment 0 1 2 3 4 5 6 7 8 9 Kingpin angle (degrees) Caster angle effects on the total resistance torque at different vehicle The total resistance torque distribution on Caster angle effects Changing in Caster vehicle wheel alignmen

Conclusion and future plan:

The Total Resistance Torque by Lateral Force F

Specific results:

- The main conclusion obtained in this Capstone project is how the wheel alignment especially Caster angle and Kingpin angle affect to the resistance moment in collaboration with specific factors such as vehicle mass, vehicle velocity,... Through all the figures mentioned above, we can conclude that wheel alignment has the huge impact on the total steering resistance torque in collaboration with vehicle mass and vehicle speed.
- In the future, it is recommended to develop this steering mechanism model and going further to simulate different situations by assist simulator such as Matlab/Simulink base on all relevant theories that mentioned in this Capstone project to provide the exact results in comparision with reality.

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