

Steering Feedback: The Math Behind Road Feel

Jenny Guanni Qu, Mentor Simon Du

University of California, Davis

February 26, 2025



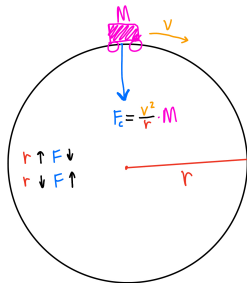
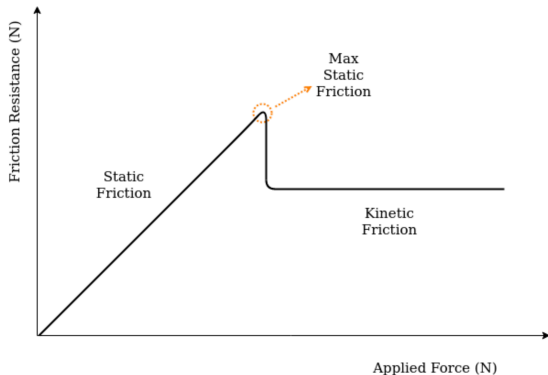
Motivation

Have you ever wondered why some cars feel more "alive" on the road while others feel numb? (sensation of tires wanting to return to neutral) Why do you feel every bump and imperfection in one car but barely notice them in another? How do race car drivers achieve high turning speed while keep control of the vehicle?



Figure: Tire Slipping

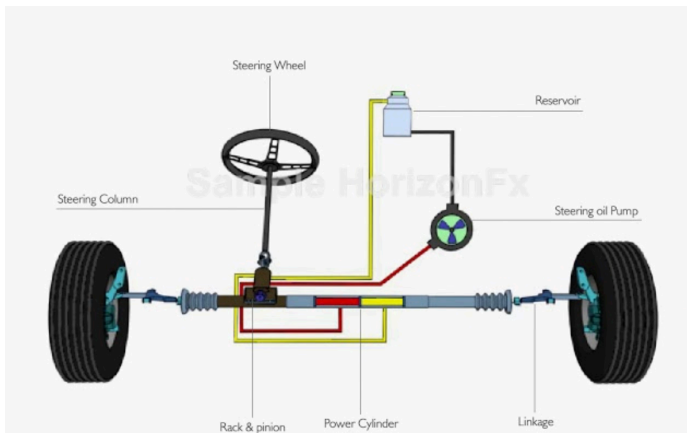
Tire Grip: Static Friction vs. Dynamic Friction



$$F_{centripetal} = F_{friction} = \frac{v^2}{r} \cdot M_{car}$$

When your tire is losing grip (sliding + rotating vs. just rotating), ease turning, so tire gets grip back.

Hydraulic Steering



Hydraulic Steering

253

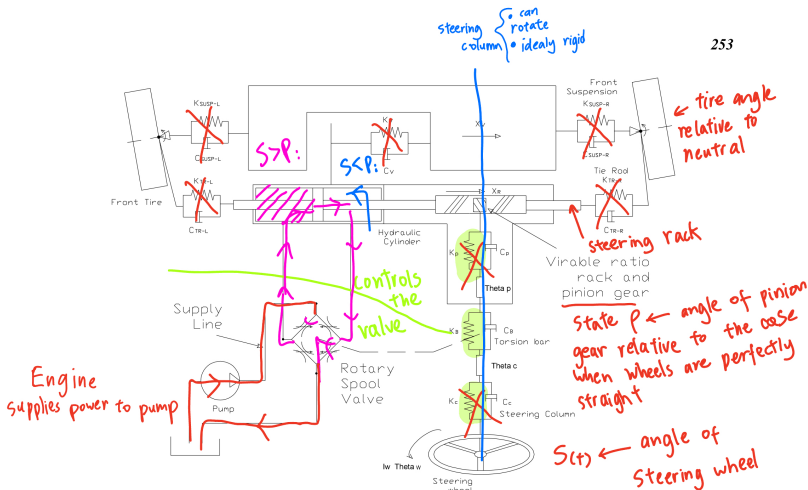
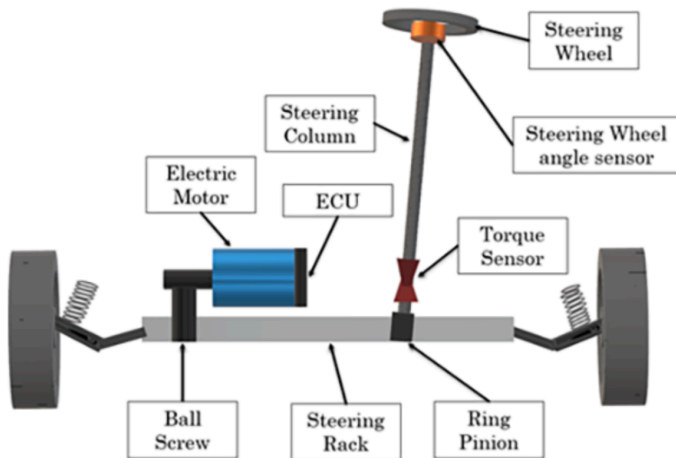
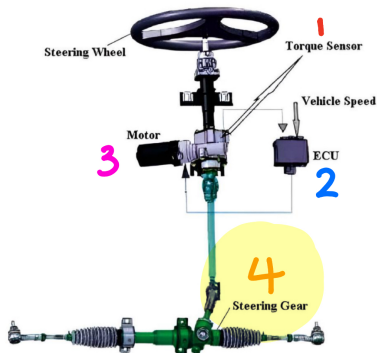


Fig. 2 Schematic of steering system model, including the connection with front suspensions

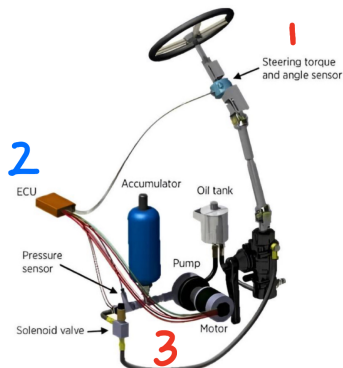
Electric Power Steering



Differences



ELECTRIC POWER STEERING



HYDRAULIC POWER STEERING

ODEs for electric power steering system is 2 orders higher.

System of Inhomogeneous ODE's

$$\textcircled{1} \frac{\text{Torque}_p^{(t)}}{\text{Radius}_p} + \underbrace{\text{Pressure}_{\text{fluid}(t)} \cdot \text{Area}}_{\text{Assist}} - \Delta x_{\text{rack}}^{(t)} \cdot C_L = M_{\text{rack}} \cdot \ddot{\Delta x}^{(t)}$$

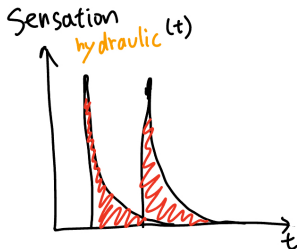
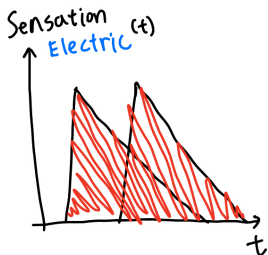
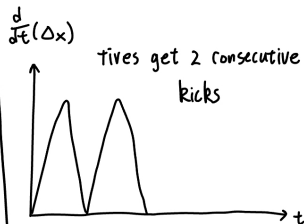
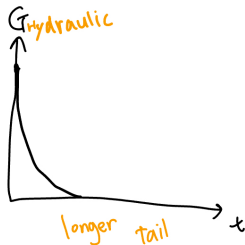
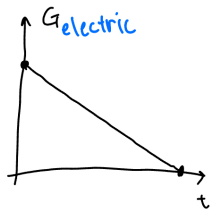
$$\textcircled{2} (s-p)K_B = I_s \cdot \ddot{\theta}$$

torque at steering wheel

$$\textcircled{3} p \cdot \text{Radius}_p = \Delta x_{\text{rack}}^{(t)}$$

$$\textcircled{4} (s-p)K_v - \dot{\Delta x} \cdot C_L = M_{\text{fluid}} \cdot \ddot{\Delta x}_{\text{rack}}^{(t)}$$

Difference in Green's Functions



$$(T^{(n)} * G)(t) = I_{\text{steering wheel}} \cdot \ddot{S}(t)$$

Summary

Electric Power Steering ODEs is 2 orders higher than Hydraulic ODE's

→ Electric Power Steering Green's Function Has Longer Tail

→ Less Bump Sensation Felt by Driver

Thank you! Any questions?