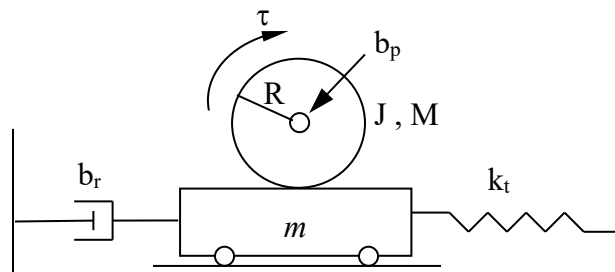


Mid-Semester Group (4 members) Project (Due ~ 3/18/2020 with 30 Minute Group Interview Quiz)

Part I

Consider the rack and pinion where the tire force during turning is modeled as a spring (this is the force that provides what is known as the aligning moment in your car which causes the steering wheel to “straighten” if you remove your hand from the steering wheel in a turn).

- Determine the equation(s) of motion for the system. Calculate the system gain and phase and plot the corresponding bode plot and step response.
- Approximate the rack and pinion with a first order model. Compare your simplified model with the actual model from part a. Plot the bode plot and step response on the same graph as the actual model.
- Design a simple proportional controller using your simplified model to control the position of the rack with no steady state error. Design the controller such that the rack achieves the desired position in approximately 2 seconds. Verify the performance of the controller on the real rack and pinion model (provide plots of the rack position and input torque).
- Redesign the controller on the simplified model to achieve the desired position in less than 0.2 seconds. Check the performance on the real rack and pinion model (again providing plots of rack position and input torque). Why is the designed performance not met on the real system with this new design specification? Why is this new result potentially bad? How might you fix the results to get the desired quick response you designed for?



| m (kg) | M (kg) | bp (Nms) | bt (Ns/m) | Kt (N/m) | J (kg-m ²) | R (m) |
|--------|--------|----------|-----------|----------|------------------------|-------|
| 0.4 | 0.3 | 0.0002 | 10 | 12 | 0.00002 | 0.01 |

Part II.

Develop a model for the suspension of your car (vertical motion only).

- Determine a method to take measurements on your system. Collect experimental data using your measurement system on your car and determine **ALL** of the parameters for your model **experimentally**.
- Where are the eigenvalues located? What is the corresponding damped and natural frequencies and damping ratio?
- Simulate the step response of your model and compare to what you saw experimentally.
- Calculate the system gain and phase and plot the corresponding bode plot. Return to your vehicle and perform a new experiment to validate the key values (e.g. corner frequency, max gain) on the bode plot.