Department of Mechanical Engineering
University of Bath

ME40064: System Modelling & Simulation
ME50344: Engineering Systems Simulation

Assignment 3: Simulink Modelling of Dynamic Systems

The overall aim of this assignment is to develop, verify, and use a model of a ½ car system, building on the ¼ model in the tutorials.

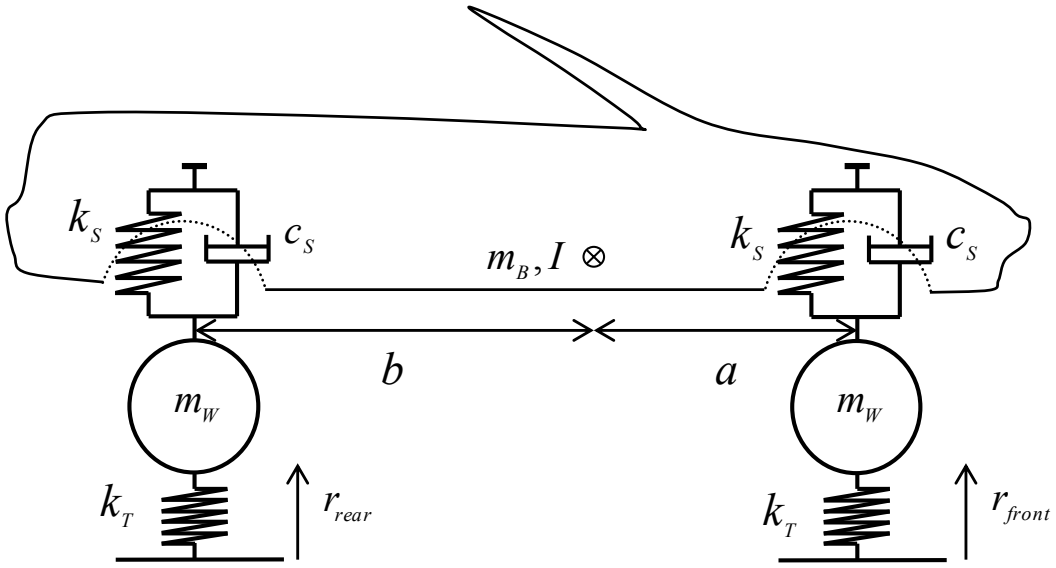

Figure 1: Representation of the 1/2 car model

Having completed Tutorial 9 you will have developed the suspension and wheel models. The main changes will be in the body model, which now represents ½ a car, and couples together the front and rear wheel assemblies. The equations of motion of the 1/2 car body are as follows:

$$m_B \ddot{s}_B = F_{front} + F_{rear} - m_B g$$
$$I\ddot{\theta} = aF_{front} - bF_{rear}$$

where s_B and θ are vertical (positive up) and pitch (anti-clockwise) displacements about the centre of mass, and F_{front}, F_{rear} are the upward forces exerted by the suspension systems on the body, at the front and rear, respectively. The equations for the wheel and suspension models are as before.

The parameters for this model are given below:

Wheel: $m_W = 20$ kg, $k_T = 14 \times 10^4$ N/m

Suspension: $k_S = 2 \times 10^4$ *N/m,* $c_S = 600$ *Ns/m* (under contraction) & *1200 Ns/m* (under extension). Spring hardening parameters: $k_{Sstiff} = 20k_S$, $x_0 = 0.2$

Body: $m_B = 500$ *kg,* $I = 600$ *kg/m*^{2}, $a = 1.25$*m,* $b = 1.4$*m*

Part 1: Model Construction & Verification

(a) Present the verification results for the 1/4 car analysis of Tutorial 9 (body, suspension, wheel, and the complete 1/4 car), first for the linear versions, then including the nonlinear versions of spring stiffness, damping rate, and tyre stiffness (see Lecture 21 slides for details). **(10%)**
(b) Create an icon block for the 1/2 car body with suitable inputs (forces) and outputs (including vertical displacements/velocities at suspension points). Verify that your 1/2 car body model is correct and explain the reasoning behind your verification tests. **(15%)**
(c) Connect the suspension and wheel models to the 1/2 car body. Verify that the complete 1/2 car model is correct and explaining the reasoning behind your verification tests. **(15%)**

Part 2: Investigation of Car Performance

(d) Simulate the vehicle's transient response over a sinusoidal road of wavelength 1 m and height amplitude 0.01 m. Choose a range of speeds for your simulations and explain your results and their relevance to car design. **(20%)**
(e) Now choose a category of car to investigate e.g. sports car, rally car, family saloon etc. Set suitable estimated values for mass, wheelbase, centre of mass etc. for this type of car. **(40%)**

i. Define suitable performance characteristics that would be desirable for your chosen type of car and how they are typically used. For example, the system response characteristics for different types of road surface inputs, such as sinusoid, step, potholes, bumps etc. This could be for both body mass in pitch and vertical motion, and wheel vertical motion. Do you need to prioritise vehicle performance or passenger comfort?
ii. Investigate the sensitivity of the car's performance to design variables such as suspension stiffness & damping and tyre stiffness, as well as variations in wheelbase, location of centre of mass, and moment of inertia around your typical values. Use your model to investigate what the optimal parameter values/ranges for your chosen type of car are, and why?

The assignment should be written up as a concise report showing your Simulink models, model verification tests, simulation results, and conclusions. All the results should be presented clearly and properly explained. Simulink diagrams should be neatly organised and easy to read and you should demonstrate that your simulation results are converged.

See Lecture 21 slides for further details on the model and what is required.

Submission

Submit your **report & the Simulink model files** using the online submission on the unit's Moodle page. As before this is an anonymous submission; therefore **do not** include your name in the report, Simulink models, or filenames, but **do include your candidate number**. There is a **word limit of 2000 words.**

Your report will be marked against the following criteria:

- Correctness of model & numerical results
- Clarity of written explanations
- Clear presentation of report content, results plots, and Simulink diagrams
- Rigour of model verification and simulation convergence testing
- Thoroughness and real-world relevance of the performance investigation

Deadline: 4pm on Monday 13th January 2020.