ME131 Vehicle Dynamics and Control

HW5: Traction Control

Assigned: 3/6/2018 Due: 3/20/2018, 11:59pm (On bCourses)

Please submit your homework solutions on bCourses as a single PDF of your solutions. When videos are required, please only submit the link as part of the solution PDF document. Late homeworks will be penalized.

Problem 1 Traction Control Design (50pt)

In this problem you will design a traction control system in MATLAB SIMULINK using a simple PI controller. Available template file and tire model data are on bCourse:

- `tractionControlSystem.slx`
- `tireForceModel.mat`
- `parameter.m`

Consider a simple vehicle longitudinal dynamics model (discussed in class and reported below):

$$m\dot{V}_x = 2F_{xd} \tag{1}$$
$$J_e\dot{\omega}_e = -b_e\omega_e + T_c - 2Rr_eF_{xd} \tag{2}$$
$$T_c = T_{eng}(t-\tau_f) \tag{3}$$

where

- The vehicle is front driven.
- $m = 1631$ Kg is the mass of the vehicle.
- V_x is the longitudinal velocity.
- F_{xd} is the front tires traction force. (Note we have a 2 factor since there is a front-left and a front-right tire).
- $J_e = 0.28$ Kg m^2 is the effective inertia reflected to the engine.
- $R = 0.12055$ is the overall gear reduction ratio.
- ω_e is the angular velocity of the engine.
- $b_e = 0.008$ Kg m^2/s is the damping coefficient of the engine.
- T_{eng} is the desired combustion torque from the engine. T_c is the actual (delayed) combustion torque.
- $r_e = 0.35$ m is the effective radius of the wheel.
- $\tau_f = 0.004$ sec is time delay.

1.1 (2pt) Download the `tireForceModel.mat` and plot tire traction force [N] (`arrFl`) vs slip ratio (`arrSigma`). Based on this plot, which slip ratio σ^{des} do we want to track during a traction control? Write this value into *sigma_max* from `parameter.m`.

1.2 (3pt) Implement the longitudinal dynamics model of equation (1), (2) and (3) into Subsystem 1 (of the provided SIMULINK model) with two inputs (F_{xd}, T_{eng}) and two outputs (V_x, ω_e).
Set the initial $V_x(0) = 0.001$ m/s and $\omega_e(0) = \frac{v_x(0)}{r_eR}$ rad/s for a no-slip initial condition.

1.3 (2pt) Implement the slip ratio formula (during acceleration) in subsystem 2. Note that subsystem 2 has two inputs (V_x, ω_e). Here, we define the slip ratio as:

$$\sigma = \frac{r_e\omega_w - V_x}{r_e\omega_w} > 0 \text{ during the acceleration} \tag{4}$$

where $\omega_w = R\omega_e$ is the angular velocity of the wheel.

1.4 (2pt) Using the tire model given in `tireForceModel.mat`, implement a 1-D look-up table (there is a simulink block for this) which outputs the tire traction force for a given slip ratio. Place the look-up table in the SIMULINK file and connect it with the right signals.

1.5 (4pt) The traction controller you will design tracks a given longitudinal driven wheel speed ($r_e\omega_w^{des}$). Here ω_w^{des} can be easily derived from the desired slip ration σ^{des} and the slip ratio definition. Report the equation for $r_e\omega_w^{des}$ as a function of V_x and σ^{des} below:

1.6 (4pt)As we mentioned in class, we set the minimum idle angular velocity $\omega_e \geq \omega_{Idle}$. This means that the tracking reference should be greater than or equal to $r_e\omega_w^{des} \geq r_eR\omega_{Idle}$. Use $R\omega_{Idle} = 9\ rad/s$. Implement the desired tracking reference ($r_{desired}$) for $r_e\omega_w$ in subsystem 3 modifying the formula of the previous point to consider the minimum idle speed.

1.7 (10pt) The switch block in the SIMULINK file switches between the driver in control (and the Traction control OFF) and the Traction Control ON (and the driver not in control). Report your activation logic below and complete the switching logic in SIMULINK.

1.8 (15pt) Design a PI-controller which tracks the desired reference ($r_{desired}$) of $r_e\omega_w$. Set the simulation time span as 10 sec. Write a .m file to run `parameter.m` and `tractionControlSystem.slx` in MATLAB and show following plots.(You need to send the Simulink data to MATLAB workspace and write a code for the plots.)

(a) Plot V_x[m/s] and $r_e\omega_w$[m/s] vs time[sec] in one plot.

(b) Plot the reference $r_{desired}$[rad m/s] vs time[sec]

Tune the PI-controller using whichever method you like; by trial and error is fine.

Your closed-loop plots should be qualitatively look like Fig. 1 where green is the desired driven wheel speed, red is the measured driven wheel speed and blue is the vehicle speed V_x (measured through the non-driven wheel speed):

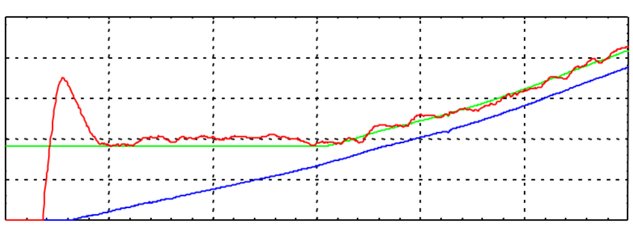

Figure 1: Reference input of the traction control

(Note: this plot is from an actual car and you might have less overshoot and dynamics might look different).

1.9 Show the benefits of having the traction control on. In particular:

(a) (2pt) Modify the SIMULINK file so that the traction control is off. Save this new file as `NoTractionControl.slx`. (Remember to upload this file to bCourse)

(b) (3pt) Plot V_x[m/s] and $r_e\omega_w$[m/s] vs time[sec] in one plot when traction control is off. Explain what you observe.

(c) (3pt) Plot V_x[m/s] vs time[sec] of both cases (on and off) in one plot. Is the result reasonable? Explain what you observe.

Upload all your files (zip your working folder) in the zip submission file.