Kapitel 5

Driveline Oscillations

5.1 Introduction and Purpose

The purpose of the laboration is to study the resonances in a drive line, and to study how the oscillations can be damped. One important case where drive line oscillations are introduced is during tip-in and tip-out manouvers, i.e. during changes in accelerator pedal position causing the drive line torque to go from negative to positive and vice versa. The task in this laboration is to design and implement a controller that damps oscillations during tip-in/tip-out. The controller will then be tested on a realistic drive line model provided on the course website. The model is of a typical passenger car. To resemble a real case only the engine speed sensor will be available for "measurements" in the simulation model. This sensor is chosen because it is typically the one in the drive line with sufficient resolution for the given task. Data for the studied car is listed in Section 5.6.

5.2 Examination

To achieve the grade passed on this laboration written solutions to the prerequisites and the exercises have to be handed in before the deadlines given on the course website. Append matlab code and simulink block diagrams of your implementation in the report.

5.3 Prerequisites

- Write down equations for a driveline including dynamics for engine torque, engine speed, drive shaft torsion, and wheel speed. Input to the model is demanded engine torque and output is wheel speed. Often it is sufficient to model the engine as a first order system and assume rolling condition for the wheels. To get a good enough model of the driveline it is often necessary to model drive line friction. This can be done as pure viscous friction, i.e. a friction torque that is proportional to the rotational speed. The rolling resistance can be assumed to be constant.

- Put the equations in standard linear statespace form. For example this can be done by linearising quadratic terms and let constant terms be represented by a known constant input signal. In the laboration you will be given reference values for engine torque, engine speed, drive shaft torsion and wheel speed. It is therefore wise to chose your states accordingly.

- Draw a block scheme for a control system of the driveline consisting of an observer and a state feedback controller using the observed states. As mentioned above only engine speed is available for measurments. In the laboration reference signals for the states will be given. Note that the reference states are time varying and not constant.

- Write down the equations for an observer of the drive line model.

- How can the observer gain be chosen?

- Write down the equations for a state feedback controller that uses the observed states. Remember that you will be given reference values for the states engine torque, engine speed, drive shaft torsion, and wheel speed.

- How can the feedback gain be chosen?

5.4 Exercises

Download the driveline model from the course homepage. All your implementations should be done in the "car/car_model/controller"-block. There is also a script "DoSim.m" that initializes the model, simulates it, and plots relevant signals.

- Implement an observer for the driveline.

- Demonstrate the performance of the observer with plots of the observed and the real drive line variables (For drive shaft torsion there is no real measured signal). Try the observer both with your calculated observer gain and with zero observer gain, i.e. pure simulation.

- Implement a state feedback controller that that damps the drive line oscillations. In the controller block reference states are already given. Use them to try to damp the oscillations in wheel speed and wheel acceleration.
- Demonstrate the performance of the controller with plots of the drive line variables both in damped and undamped mode.

5.5 Hints

- First, make sure that your observer is correct. Try it both in pure simulation and with your calculated observer gain.
- There are different ways to design the state feedback controller. One way is to choose the feedback gain such that the poles of the closed loop system is placed at desired places. When doing this it has to be assured that the commanded control is of reasonable size and can be actuated. One way to take this into account is to use LQ-design which finds the feedback gain that minimizes a criteria that is quadratic in states and control.
- There is a torque limitation of 400Nm in the car model. This means that if your controller tries to acquire to much torque your observer will be inaccurate. Therefore it is wise to include this torque limitation on your controller output.

5.5.1 Useful matlab commands

Type *help control* in matlab to see the help for the control toolbox.

Specific useful commands are:

- *care*: Solves the continuous algebraic riccati equation.
- *kalman*: Continuous- or discrete-time Kalman estimator
- *ss*: Cretates state space model object. SS(A,B,C,D) creates a SS object representing the continuous-time state-space model.
- *place*: Pole placement.
- *lqr*: Linear-quadratic regulator design.
- *lqe*:Kalman estimator design.

5.6 Vehicle Data

Parameter	Value	Unit
Vehicle mass	1500	[kg]
Front crossectional area	1.5	[m^2]
Wheel radius	0.3	[m]
Wheel inertia	0.6	[kgm^2]
Air drag coefficient	0.3	[-]
Rolling resistance coefficient	0.015	[-]
Engine inertia	0.2	[kgm^2]
Engine step response time constant	0.1	[s]
Engine maximum torque	400	[Nm]
Clutch stiffness	10000	[Nm/rad]
Clutch damping	30	[Nms/rad]
Gear ratio 1:st gear	3.4	[-]
Gear box inertia 1:st gear	0.13	[kgm^2]
Gear box friction	0.1	[Nms/rad]
Final drive gear ratio	3.4	[-]
Final drive inertia	0.1	[kgm^2]
Final drive friction	1	[Nms/rad]
Drive shaft stiffness	1000	[Nm/rad]
Drive shaft damping	1	[Nms/rad]
Propeller shaft stiffness	5000	[Nm/rad]
Propeller shaft damping	15	[Nms/rad]

Tabell 5.1 *Data for the passenger car studied in the laboration.*