

Høgskolen i Buskerud (Buskerud University College)
SEMR3401 Styring av mekatroniske systemer

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Project assignment: Clutch Servo

1 Introduction

Due to fuel economy and the amount of torque transferred from the engine to the driveline, modern automatic heavy duty truck transmissions can not rely on the commonly used combination of torque converters and planetary gears. An automated solution consisting of a manual transmission and a conventional diaphragm spring clutch is thus the preferred solution. In the automotive industry, this is called an AMT solution. The comfort of the AMT system is comparable to that of a conventional automatic transmission, but the robustness and fuel economy is significantly better.

In order to operate the clutch in an AMT equipped vehicle, an actuator is needed. As heavy duty trucks already have compressed air onboard, the actuator is of the pneumatic type. The air supply to the actuator is electronically controlled by a set of solenoid valves. The actuator position is available for feedback. A truck with AMT that wants to start running forward can be designed with a four step procedure:

1. Disengage the clutch by moving the actuator piston from 0 mm to 20 mm. At that position the clutch is completely disengaged.
2. Change gear
3. Go down to the position where the clutch discs nearly touches (approximately 12 mm)
4. Engage the clutch depending on the acceleration pedal position, piston position and time.

2 Information about the system

A control system for the electro-pneumatic clutch actuator is needed to manage steps 1, 3 and 4 above with satisfactory performance. This

exercise will be focusing on step 1 and 3. Setup for the electro-pneumatic clutch actuator can be seen in Figure 1

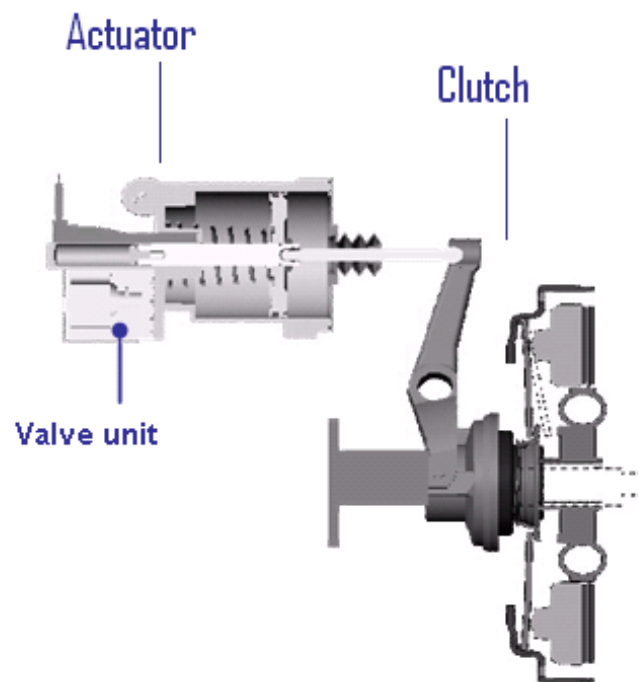


Figure 1: Electro-pneumatic clutch actuator

3 Mathematical model

The following variables are used in the mathematical model presented below:

y [m]	Position
v [m/s]	Velocity
p [Pa]	Pressure
w [kg/s]	Mass flow through valve
u [kg/s]	Demanded mass flow
f_s [N]	Spring force

The clutch actuator is a mass-spring-damper system. A simplified model of the clutch actuator is as follows:

$$\dot{y} = v \quad (1)$$

$$M\dot{v} = -f_s - Dv + A(p - P_0) \quad (2)$$

$$\dot{p} = -\frac{Avp}{V_0 + Ay} + \frac{RT_0w}{V_0 + Ay} \quad (3)$$

$$w(s) = \underbrace{\frac{1}{\tau_w s + 1}}_{H(s)} u(s) \quad (4)$$

Position measurements are for the piston position in the actuator, and we have assumed that $y = 0$ when the clutch is completely engaged.

The spring force f_s is a function of the piston position y . This function is defined in Appendix A.

The parameters of the model are as follows:

Parameter	Value	Description
M	10 [kg]	Actuated mass
D	2000 [N/(m/s)]	Viscous friction
A	0.0123 [m ²]	Piston area
P_0	100000 [Pa]	Atmospheric pressure
R	288 [J/(kgK)]	Gas Constant
T_0	293 [K]	Temperature
τ_w	0.05 [s]	Valve time constant
V_0	0.0008 [m ³]	Actuator volume at $y = 0$
w_{\max}	0.020 [kg/s]	Maximum inlet flow
w_{\min}	-0.020 [kg/s]	Maximum exhaust flow

4 Tasks

1. Explain the physical meaning of the individual terms in each of the equation (1) – (4). Is the model linear or nonlinear?
2. The functional relation between f_s and y , say,

$$f_s = g(y) \quad (5)$$

is defined in Appendix A. Plot f_s as a function of y .

3. Implement a simulator of the clutch actuator in LabVIEW Simulation Module. In the simulator function g in (5) should be implemented using *table lookup* (or interpolation between the tabular data).

4. The position y is to be controlled by a PD-controller. Include the controller in the simulator. Tune the controller (experimentally, on the simulator) so that the control system is asymptotically stable at any operating point in the range 0 – 30mm. What is the time needed to move the piston from 12mm to 20mm?

A Experimental data of spring position and spring force

In the following are listed experimental data of spring position y and the corresponding spring force f_s .¹

Position [m]

0
0.0012
0.0024
0.0036
0.0048
0.0060
0.0072
0.0084
0.0096
0.0108
0.0120
0.0132
0.0144
0.0156
0.0168
0.0180
0.0192
0.0204
0.0216
0.0228
0.0240
0.0252
0.0264
0.0276

¹Honestly, these values are not truly experimental. In stead, they are calculated from a fitted functional relation between position and force. This function is based on original experimental data. Neither this function nor the original data are shown in this document. Working with the numerical values presented in the appendix is therefore very similar to working with the original numerical values.

0.0288
0.0300
0.0312
0.0324
0.0336
0.0348
0.0360
0.0372
0.0384
0.0396
0.0408
0.0420
0.0432
0.0444
0.0456
0.0468
0.0480
0.0492
0.0504
0.0516
0.0528
0.0540
0.0552
0.0564
0.0576
0.0588
0.0600

Force [kN]

0

2.2379

3.4580

4.1195

4.4744

4.6611

4.7554

4.7990

4.8149

4.8154

4.8076

4.7952

4.7803

4.7640

4.7469

4.7294

4.7117

4.6938

4.6759

4.6579

4.6400

4.6220

4.6040

4.5860

4.5680

4.5500

4.5320

4.5140

4.4960

4.4780

4.4600

4.4420
4.4240
4.4060
4.3880
4.3700
4.3520
4.3340
4.3160
4.2980
4.2800
4.2620
4.2440
4.2260
4.2080
4.1900
4.1720
4.1540
4.1360
4.1180
4.1000