MECH420

Sensors and Actuators

Laboratory Exercise #5:
Hydraulic Demo System with Servovalve and Analog Sensors

Lab Group:	A3
Student:	D. Student
Date lab taken:	November 27, 2019
TA:	T. A. Name

Part B: Calibration of the Displacement Sensor

The measurement results in the following table

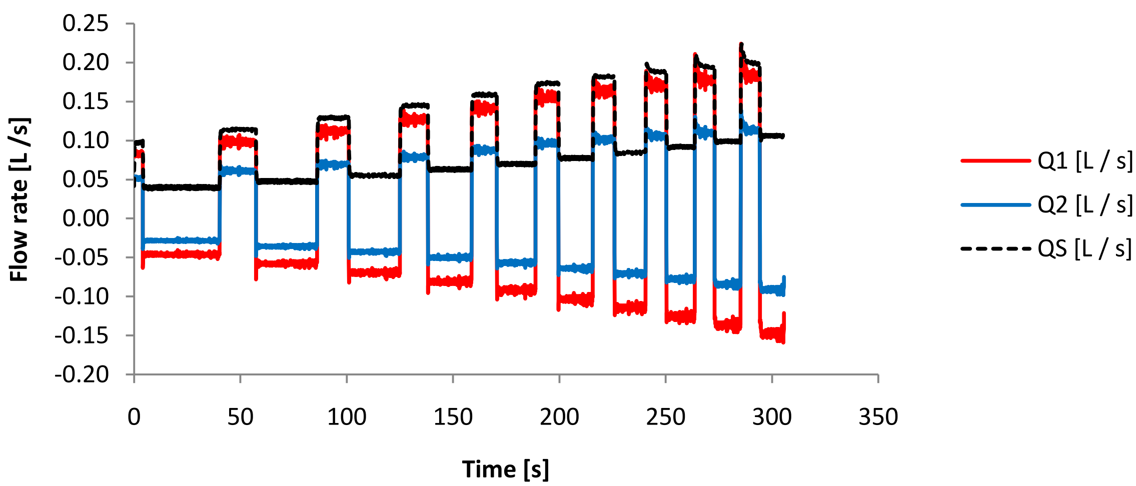
	N	x [mm]
up position	34,245	209
down position	11,148	0

were used to derive the linear calibration relation

$$x = N \cdot 9.05\ \mu\text{m} - 100.9\ \text{mm}$$

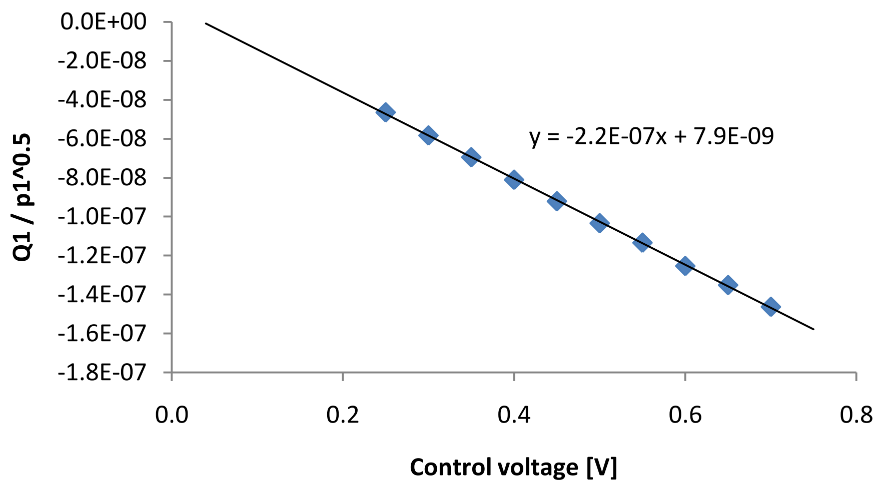
Part C: Characterization of the Servovalve

1. The counts from the position sensor are converted into positions using the calibration equation from part B. Numeric differentiation of the position data yield the velocity, which is then used to derive the volumetric flow rates for both cylinder chambers using the respective surface areas of the piston faces. The voltage signal from the turbine flow meter is also converted into a volumetric flow rate. All three volumetric flow rates are plotted over time in the following diagram:



The flow rates Q_1 and Q_2 differ only by a constant factor from each other (as derived). While Q_1 and Q_2 are positive and negative, Q_S is always positive, from the pump to the valve. The positive values of Q_1 seem to be close to the corresponding values for Q_S. The negative values for Q_2 seem close to the corresponding $-Q_S$. Differences are due to calibration errors.

2. The piston undergoes periods of lifting ($Q_1 = Q_S$) and lowering ($-Q_2 = Q_S$).
3. Flow conditions as a function of valve control voltage



5 values are sufficient.

From the linear curve fit in the graph for $Q_1 / p_1^{1/2}$ as a function of control voltage V_V as

$$Q_1 / p_1^{1/2} = -2.2 \cdot 10^{-7} \frac{\mathrm{m}^4}{\mathrm{s\,V}\sqrt{\mathrm{N}}} V_V + 7.9 \cdot 10^{-9} \frac{\mathrm{m}^4}{\mathrm{s}\sqrt{\mathrm{N}}}$$

the two unknowns

$$V_{Vo} = 0.036\,\mathrm{V}$$

and

$$K_i = -2.2 \cdot 10^{-7} \frac{\mathrm{m}^4}{\mathrm{s\,V}\sqrt{\mathrm{N}}}$$

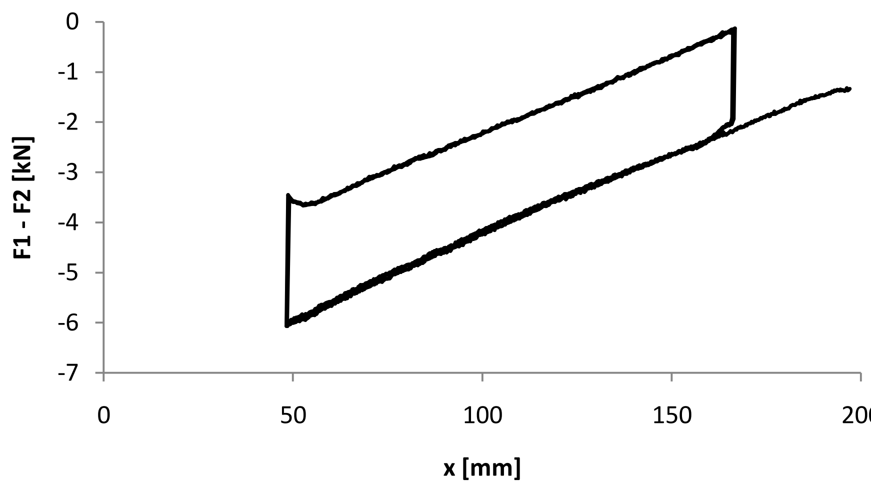
can directly be derived.

Part D: Load Dependent System Performance

The displacement is calculated using the calibration equation from part B, and the forces F_1 and F_2 are calculated as in part C. The slope of the two slanted sections of the graph

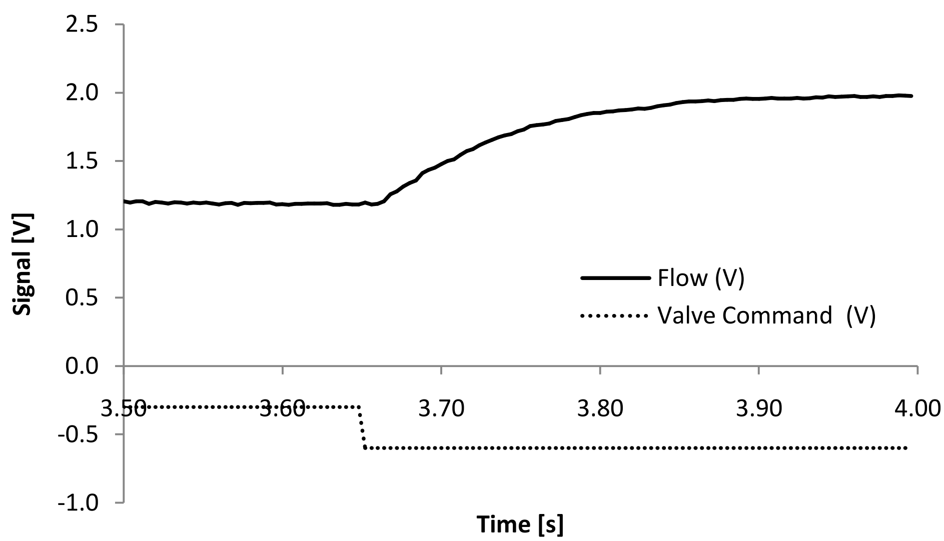
$$k = \frac{\Delta F}{\Delta x} = \frac{3.26\,\mathrm{kN}}{101\,\mathrm{mm}} = 32.3\,\mathrm{kN/m}$$

corresponds to the spring stiffness k.



Part E: Dynamics of the Hydraulic System

1. As shown in the figure below at the example of the voltage signal from the flow sensor, there is no delay in the system response within the time resolution of the measurements. Similar observations were made for the other signals as well.



2. The time constant

$$\tau = 80 \text{ ms}$$

is found for a 63% change in the signal amplitude between the steady state and the signal peak as response to the step change in the valve control voltage.