Case Study – Spring-Loaded Diagraphragm Actuator

The system shown in Figure P5.18(a) is a single-acting rolling diaphragm actuator with a spring return. There is no preload on the spring. The actuator is driven from a pressure regulator through a fast-acting solenoid valve. In series with the solenoid valve is a small orifice. The system has been built and instrumented in the lab. The components have been measured, and their values are as follows:

m = mass of actuator = 0.1 kg $\qquad$ k_s = stiffness of spring = 1.33 N/mm

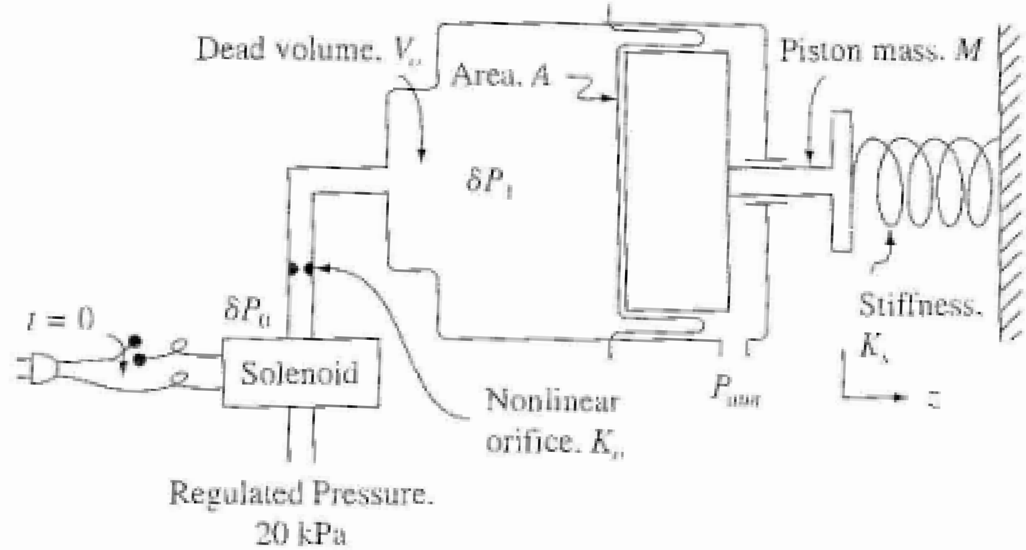
A = area of actuator = 1774 mm^2 $\qquad$ K_0 = orifice coefficient = 23.8×10^9 kN s^2/m^8

V_0 = volume = 15,000 mm^3

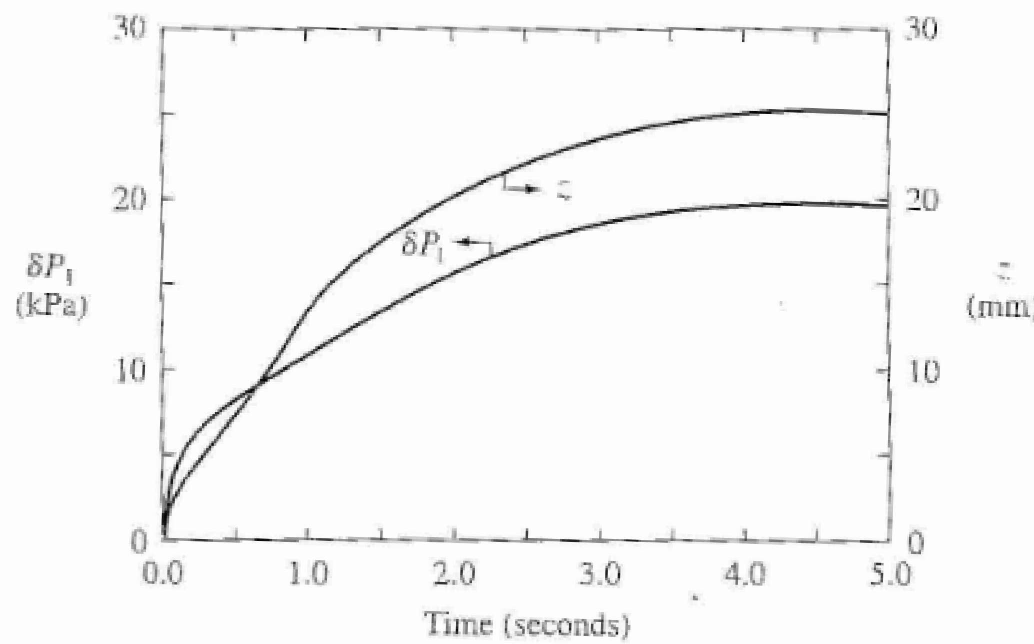
a. First, *model* the system, neglecting the effects of the mass and considering the incompressible flow equation. (See problem 5.17.) *Derive* the system dynamics equations for the actuator. *Express* the equation in the state-space format, and *state* equations that can be used for the internal pressure and position of the actuator, based upon the state variables. Next, *model* the system, considering the mass. *Derive* a state-space representation of the system, and *state* the equations for pressure and position as a function of the state variables.

b. *Obtain* the simulated response with a step input of pressure 20 kPa for both cases in part a. *Plot* δP_1 and z. *Compare* your results with the experimental response given in Figure P5.18(b). *What* can you suggest that has not been modeled or taken into consideration that would account for the differences in the simulated and experimental responses?

c. From part b, *discuss* which model should be used (i.e., can the mass be neglected in this case?) and *how* could you determine from the equations whether mass would be important.



(a) Configuration.



(b) Transient response.

Figure P5.18 Spring-loaded diaphragm actuator.