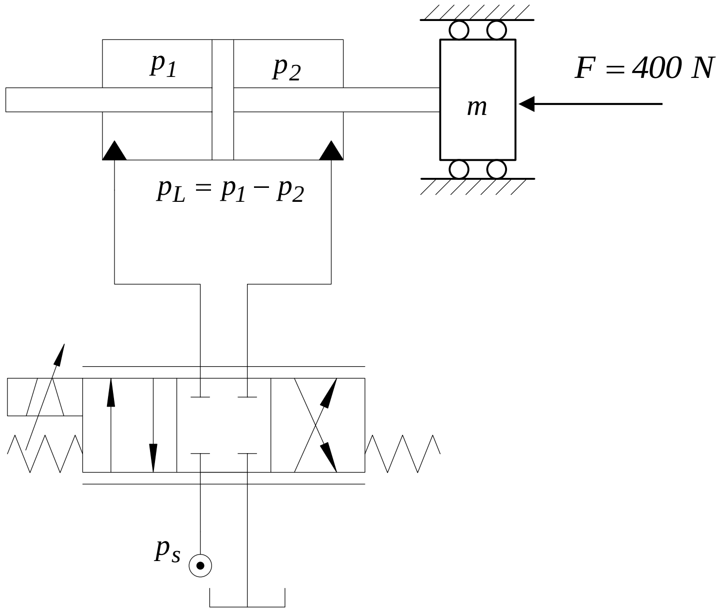
Problem 1

A standard servo system is shown below.



The total stroke of the cylinder is $h = 2.4\ m$, the diameter of the cylinder piston and cylinder rod are $D = 40\ mm$ and $D_R = 25\ mm$, respectively. The volume of each of the lines connecting the servo valve to the cylinder is $V_{L1} = V_{L2} = 1\ dm^3$. The oil stiffness is $\beta = 1000\ MPa$ and the density is 875 $\frac{kg}{m^3}$. The mass of the payload is $m = 1200\ kg$. The constant supply pressure is set at $p_S = 60\ bar$.

The task of the servo system is to move the mass m a distance of $\Delta s = 1.2\ m$ within a period of $\Delta t = 2\ s$.

a) Compute the minimum stiffness of the mechanical-hydraulic system.

$611.2\ \frac{N}{mm}$

b) Compute the minimal eigenfrequency of the mechanical-hydraulic system.

$22.6\ \frac{rad}{s}$

c) Compute a velocity reference for the motion task. Use a trapez profile (constant acceleration - constant velocity - constant deceleration) with a ramp time $t_R = \frac{6}{\omega_n}$. The start position of the piston is not known, hence the minimal eigenfrequency should be used to compute the ramp time. $t_R = 0.266\ s$ and $v_0 = 0.69\ \frac{m}{s}$

d) Compute the maximum and minimum load pressure $p_L = p_1 - p_2$.

$p_{L,max} = 46\ bar$ and $p_{L,min} = -35.6\ bar$

e) Compute the maximum flow requirement, Q_L. $31.8\ \frac{l}{min}$

f) Compute the maximum value, $Q_{NL,max}$, of the no load flow, $Q_{NL} = Q_L \cdot \sqrt{\frac{p_S}{p_S - p_L}}$

$65.8 \ \frac{l}{min}$

The servo valve can be chosen between three valves. Each of the valves has a frequency range (phase = -90 deg) of $f_{v@90^\circ} = 15Hz$. For each of the valves the rated flow is measured at a rated supply pressure of $p_r = 10bar$. The rated flow of the valves are:

$Q_{r1} = 10\frac{l}{min}$ $\quad Q_{r2} = 20\frac{l}{min}$ $\quad Q_{r3} = 40\frac{l}{min}$

g) Determine which of the three valves that can be used.

#3

Use the chosen servo valve with $f_{v@90^\circ} = 15Hz$. The valves rated flow is measured at a rated supply pressure of $p_r = 10bar$. The rated flow of the chosen valves is: $Q_r = 40 \frac{l}{min}$. Assume $C_d = 0.6$ for this valve.

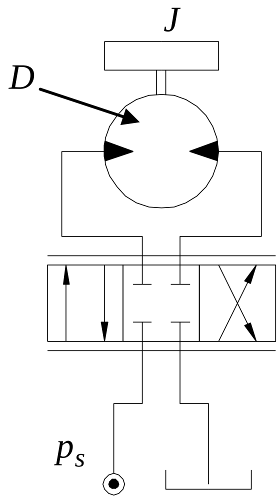
h) Linearize around two steady state situations: maximum speed, $v_0 = 0.69 \frac{m}{s}$ and $v_0 = 0.0 \frac{m}{s}$ at the beginning (no load pressure and no load flow) by solving for the steady state variables: $Q_L^{(ss)} = Q_v^{(ss)}$, $p_L^{(ss)}$ and $u^{(ss)}$. $31.7 \frac{l}{min}, 5.22 \ bar, 0.339$ and $0 \frac{l}{min}, 0 \ bar, 0$

i) Set up a position servo to drive this system by computing the proportional gain, K_p, using $K_p = 0.7079 \cdot \frac{2 \cdot \zeta_{mh} \cdot \omega_{vmh}}{K_{mh}}$. In the situation at the no velocity, no load pressure and no load flow steady state situation use $u_{lim}^{(ss)} = u_\epsilon = 0.05$ according to Eqs. (7.26) and (7.27). $2.12 m^{-1}$

j) Verify the performance by time domain simulation of the system.

Problem 2

A hydraulic servo system is shown below. The hydraulic motor drives a mechanical system that can be considered a pure inertia of $J = 18\ kg \cdot m^2$, i.e., no static load. The mass moment of inertia of the hydraulic motor can be ignored.



The motor has a displacement $D = 225\ \frac{cm^3}{rev}$. The oil stiffness is $\beta = 1000\ MPa$. The volume of the lines between the valve and the motor are $V_{L1} = V_{L2} = 0.15\ dm^3$. The supply pressure is held constant at $p_S = 240\ bar$. The system should be able to drive the motor at a speed of $n = 1800\ \frac{rev}{min}$ while the load pressure is $p_L = 50\ bar$.

a) Find a suitable valve specification for controlling this system. Assume: $p_r = 70\ bar$ and $C_d = 0.6$. $Q_r = 270\ \frac{l}{min}$ @ $p_r = 70\ bar$ and $\omega_v = 69.9\ \frac{rad}{s}$.

b) Linearize around the 0-position by solving for the steady state variables: $Q_L^{(ss)} = Q_v^{(ss)}$, $p_L^{(ss)}$ and $u^{(ss)}$. $0\ \frac{l}{min}, 0\ bar, 0$

c) Set up a position servo to drive this system by computing the proportional gain, K_p, using $K_p = 0.7079 \cdot \frac{2 \cdot \zeta_{mh} \cdot \omega_{vmh}}{K_{mh}}$. Use $u_{lim}^{(ss)} = u_\epsilon = 0.05$ according to Eqs. (7.26) and (7.27). $0.181 rad^{-1}$

d) Verify the performance by time domain simulation of the system.